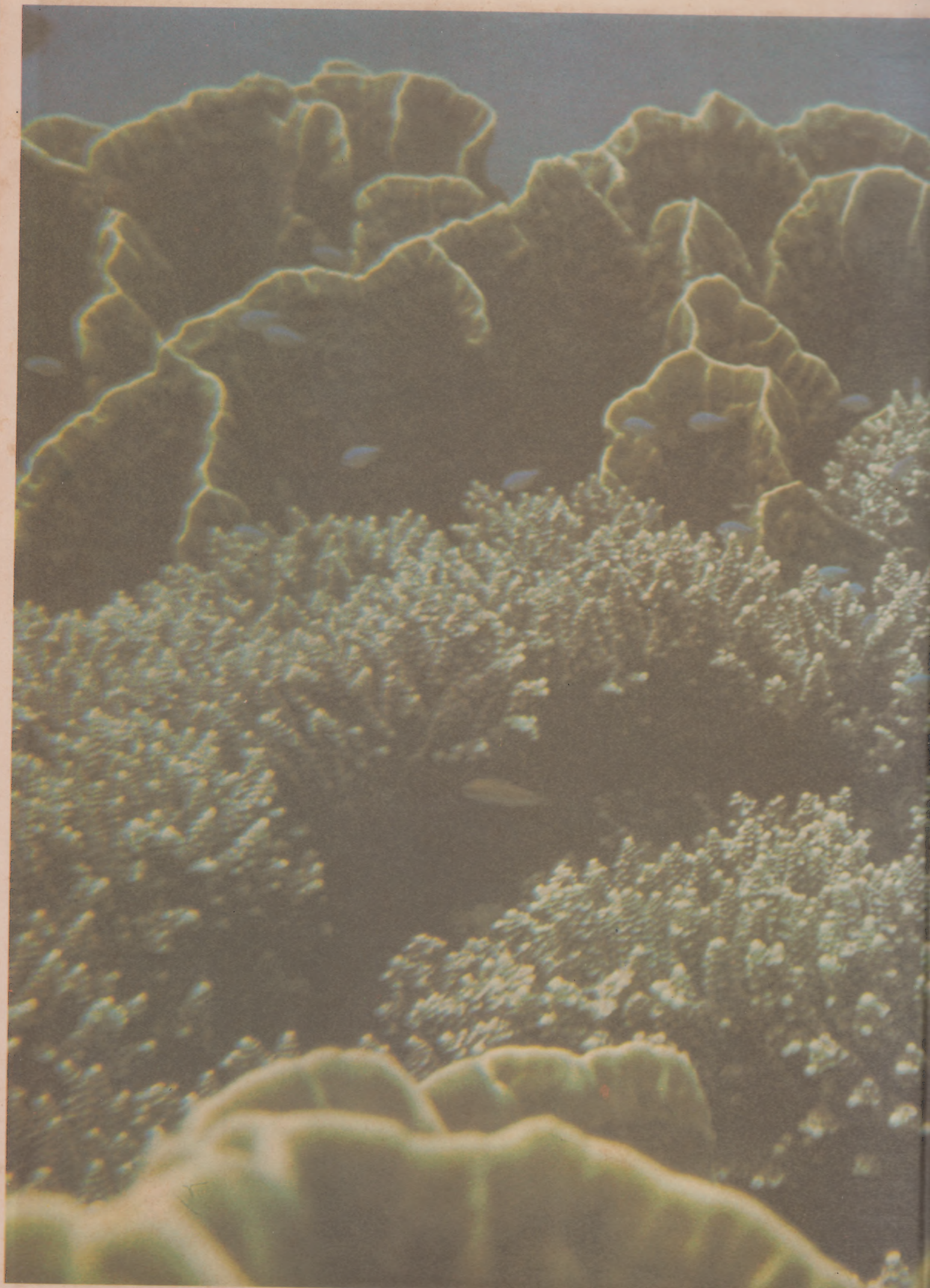
THE CHILDREN'S TREASURY OF KNOWLEDGE

Underwater Life



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ON THE COVER

A salmon embryo, eyes clearly visible, begins to emerge from the egg. The egg's yolk, 6–8 mm. in diameter, will be the embryo's food for weeks.

THE LIVING WATERS

Perhaps our planet is misnamed. With more knowledge of the land than of the sea our ancestors called it Earth. Had they known that three fourths of the earth's surface was covered with water they might have named it Ocean. All life began in the water, and only after millions of years did some forms adapt to land. But the oceans provide more than 100 times more living space than the land and teem with many forms of life from tiny, one-celled plants to huge fish and aquatic mammals—from sunlit surfaces to murky depths several kilometres down. Thus we call our oceans the living waters.

The quiet, blue-green world of the coral reef. A solitary batfish floats at the edge of a cliff covered with hard and soft corals

THE MARINE WORLD

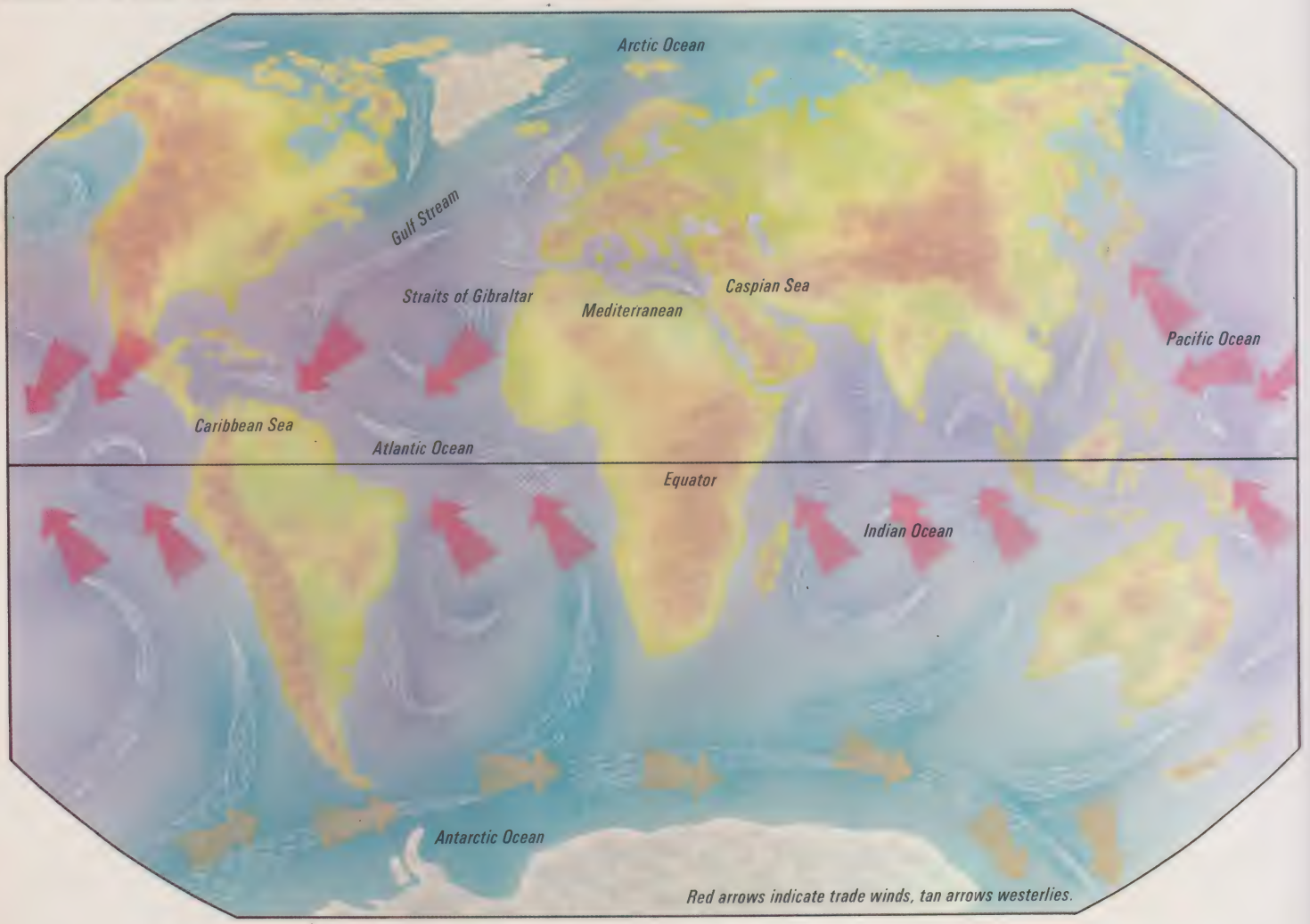
MAIN WATER MASSES

Hundreds of years ago the Greeks and other inhabitants of early civilisations along the Mediterranean Sea knew of a body of water just beyond the Straits of Gibraltar. They believed it to be not much larger than a river. This "river" was of course actually the Atlantic Ocean, one of the vast bodies of salt water that cover most of the globe. This salt water, found in oceans, seas and certain lakes, comprises more than 95% of the total water on the earth's surface. Less than 5% is fresh water, and most of this is locked up in the polar ice caps and glaciers. The water in areas where salt and fresh water meet—low-lying coastal swamps and the wide parts of rivers near their mouths, called estuaries—is known as *brackish*.

The largest bodies of salt water are the oceans. Some people count five—the Atlantic, Pacific, Indian, Arctic and Antarctic. Others claim that the Arctic and Antarctic really belong to the other three. But if you look at the map, you will see that all the oceans are connected with one another to form what is really one great World Ocean. In this book we will refer to the area covered by the Indian and Pacific Oceans as the Indo-Pacific because the environments and animal types of the Indian and Pacific Oceans are alike.

Smaller bodies of salt water that are connected to oceans but usually partly enclosed by land are called seas. The word sea is also used to describe a few landlocked bodies of water that are really large saltwater lakes—like the Caspian Sea and the Dead Sea—and certain areas within oceans themselves such as the Sargasso Sea, which is found in the Atlantic Ocean.

BODIES OF WATER, CURRENTS AND WINDS



CURRENTS AND WINDS

The earth's waters are constantly moving. Plants and animals living in the water depend on this motion because it brings essential minerals, oxygen and sources of food to them. It also distributes certain plants and animals over new feeding grounds and determines the abundance of microscopic plants and the tiny animals feeding on them that make up the drifting life in the sea's upper surface layer.

Currents and winds, especially at sea, are important movers of water. Currents are river-like flows that have a profound effect on marine habitats. Some are warm and flow in upper levels, while other currents are cold and flow deep in the sea, sometimes in directions totally opposite to the currents hundreds of metres above them.

Currents are partly caused by the rotation of the earth. Because the earth spins east, the oceans move west along the equator. As this happens, winds also blow west and push the surface of the sea along with them. On both sides of the equator such winds are called the trade winds, and farther north and south the winds that blow in the opposite direction, toward the east, are the westerlies, so named for the direction from which they proceed. The combined action of these winds, the spin of the earth and differences in water temperature create mighty currents, which swirl clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

UPWELLING

When deep currents meet submerged banks or coastal shorelines, the flowing water has no place to go but up. The process of water being forced up is called *upwelling*, and it also occurs when surface water is driven away from the land by offshore winds to be replaced by water from below. Upwelling brings rich nutrients from deeper levels to the plant and animal life living near the surface, making such areas the most productive fisheries in the world.

WAVES

Waves are movements of water at the surface, appearing as advancing ridges blown along by the wind. Their size depends on the strength of the wind and the distance they have travelled. Waves in a quiet bay may appear as no more than small ripples; those on a stormy ocean coast can rise like giant walls of water before they break. Waves are important to life in surface waters, as they help to keep these waters well mixed with air and thus full of oxygen. Along the shore the continuous pounding of the surf creates a violent environment, forcing the plants and animals that live there to adapt in various ways. Some have tough armour-like shells and anchor themselves to rocks. Others fix themselves to the ocean floor or burrow into it.

TIDES

Twice every day, great volumes of water flow toward shore and then out again to the sea. These water movements are called tides, and they occur because of the gravitational pulls of the sun and moon. Even though the sun and moon are very far away from the earth, the gravitational pull of these two celestial bodies can move the seas in their direction. As the tides alternately cover and uncover the narrow strip of coastal land that lies between the high-tide and low-tide marks, the many plants and animals that live there must adapt to alternate submersion and drying-out. They also must be able to withstand rapid changes in temperature and salt content, or salinity, and the potentially harmful effects of the rays of the sun.

The rocks and sand of a beach in Wales, the picturesque mountainous region on the Irish Sea on the west coast of the British Isles, are exposed at low tide.

A rocky coastline on the Indonesian island of Sulawesi. The barnacles that live on rocks adapt to harsh conditions produced by tides and waves.

THE HYDROLOGIC CYCLE

Just as there is a continuous circulation of water within the oceans, so, on a larger scale, there is constant circulation within the earth's total water system. In this hydrologic or water cycle, the sun causes water from the ocean surface to evaporate and, leaving the salt behind, transforms it into vapour in the form of clouds. When the clouds cool they release water as rain, hail or snow. Most of the water falls back into the ocean, but about a fourth of it falls on land, where much of it evaporates back into the air or is absorbed by plants. Some water seeps into the ground, where it is stored for a time in the underlying water table. The remaining water gathers in lakes, streams and rivers and eventually completes the cycle by flowing back into the sea.

MARINE HABITATS

Comprising 1,400 million cubic kilometres, the ocean is a huge living space. Within this vast environment variations in light, temperature, pressure, salt content, currents, tides and wave action create different zones, each with its own particular animals.

Along the seashore where the tides move in and out, marine plant and animal life is rich and varies with the type of shore. Sandy and muddy beaches support few seaweeds, but burrowing animals such as crabs are plentiful. But on muddy beaches in the tropics, hardy mangrove trees root themselves securely in the mud, creating mangrove beaches where animals such as mudskippers thrive. Rocky shores provide firm surfaces for seaweeds and many animals, like barnacles and molluscs, that can anchor themselves against the waves.

From the seashore of each continent extends a continental shelf, which slopes downward to a depth of 200 metres to reach the continental edge. It is in these sunlit upper waters, called the photic zone, that microscopic plants and animals are found, making up the "pastures of the sea" upon which all but microscopic animals ultimately depend for food. The tiny plants also release oxygen, thereby contributing enormously to the oxygen supply vital for underwater life. Many fish are also found near the surface, and some, like manta rays and flying fish, leap out of the water. On the bottom in shallow, sunlit waters is a great variety of plants and animals.

Below the surface waters plant life diminishes as less and less sunlight enters. The dip down the continental slope is sharp, and the area from 200 metres to about 1,000 metres marks the lower limit of the region of shallow continental waters known as the twilight zone. Swimming in these waters are such important food fish as cod, herring, mackerel and anchovy, while at the bottom live animals such as crustaceans and flatfish.

From the shallows the continental slope dips down through the upper and abyssal zones to the cold, dark depths of the ocean. Giant squid are found in the abyssal regions, but the bottom dwellers below 3,000 metres—creatures like starfish, sea cucumbers and worms—are usually small, living at tremendous pressures in near-freezing temperatures. As food is scarce, they eat food debris falling from above, comb the mud for organic particles or prey on one another. Living at great depths where there is little or no light are also many strange creatures equipped with light organs or huge mouths and teeth. One fish even has an expandable stomach enabling it to swallow prey even larger than itself. We still know very little about life in the deepest parts of the ocean; the extremes of cold and pressure and the absence of light makes exploration difficult.

FRESHWATER HABITATS

Although the fresh waters of the world make up only a small proportion of the total mass of water on the earth, they provide a wide variety of aquatic environments for living things. From rain pools and ponds to vast inland lakes, from rushing brooks and underground cave streams to mighty rivers, from hot mineral springs to frozen glaciers and polar ice, life is found, usually in abundance. Even a temporary puddle is a miniature world of microscopic organisms, teeming with tiny plants and animals that live brief lives.

STREAMS AND RIVERS

The depth of the water and its speed largely determine what kinds of life are found in streams and rivers. Few plants can survive the torrential force of water in rapid streams and fast-moving mountain rivers, and the animals that live there—fish like trout and loaches, tiny crabs, certain worms and many others—cope in a variety of ways: being strong swimmers, seeking shelter under rocks or stones, burrowing into the mud or anchoring themselves with suckers to avoid being washed away by the current. Fast-flowing streams are usually clear and free of pollution.

Further downstream rivers are usually larger and move more slowly. Here there is more plant life and a greater variety of animals—worms, clams, snails and many types of fish—that feed on water weeds or grub on the bottom for rich organic material. As rivers broaden out, they flow still more slowly, and the water is usually cloudy or muddy from silt and, nowadays, often polluted.

At the mouths of rivers fish that are comfortable in brackish water, such as bluefish, shad, striped bass, and in tropical waters, pufferfish and scats can be found. Some uniquely adapted fish, such as salmon and eels, migrate freely between fresh and salt water.

Above, a shallow mountain stream, home to a variety of small underwater animals such as worms, crabs and fish.

LAKES AND PONDS

Lakes and ponds are bodies of still water undisturbed by tides, currents or appreciable wave action. Larger than ponds, lakes can be very deep, and in the lower depths, the water is cold and lacking in oxygen, thus providing a poor home for underwater animals. However, in the warm upper layers of the water, animal life abounds. It includes many food fish, such as lake trout, perch and smallmouth bass, or in tropical areas, carp and tilapia.

Ponds are small bodies of water alive with water weeds and many aquatic animals like frogs, fish and insects. In time, ponds and lakes tend to become full of silt and overgrown with weeds, whereupon they develop into swamps and bogs inhabited by fewer kinds of animals and characterised by decaying plant life. Humans are guilty of turning ponds and lakes into lifeless bodies of water by careless soil-conservation practices, thus speeding up the silting process; and by dumping sewage, factory waste and rubbish into the water.

Reeds, which are giant water grasses, extend from the shore of a tranquil lake, a freshwater habitat rich in animal life, especially in its upper layers.

CAVEWATERS

Streams and rivers flow through underground caves, carving out limestone in a constant erosive process. The fish and other underwater animals that live in these waters have become adapted to life in total darkness. Some species of cave fish are blind, their eyes long since buried in the skin. To make up for this, certain sense organs in their skin that respond to vibrations are highly developed to allow them to navigate skilfully through the water. Where there is no light, skin pigments have no purpose, so cave dwellers often have no pigment and appear pale pink, the colour of their blood. The blind Mexican cave characin illustrates well this adaptation to darkness. Unlike other characins that live in rivers above ground (see page 74), this cave dweller has tiny sightless eyes.

Adapted to a world without light, these cave-dwelling Mexican characins have no sight or protective colouring.

LIFE IN THE WATER

The great numbers of animals in the sea are adapted for living in different habitats of the water. In the vast upper regions of open water are three groups characterised by the way they move from place to place: floaters, drifters and swimmers. Across the broad expanse of sea bed, which stretches from the shore down to the ocean depths, there exists a much greater variety of animals called the *benthos*, or bottom dwellers.

An assortment of animal plankton. The large orange mass at centre is a crab larva; just above it is a V-shaped shellfish. At lower right, its eye clearly visible, is a fish larva. The long, transparent animals are arrow worms and the tiny ones crustaceans.

FLOATERS

The floaters have bodies that are lighter than sea water. Living on the surface with at least a part of their bodies exposed to the air, they are carried from place to place by winds and currents. The floaters are few in number, but include one of the most fascinating marine animals, the Portuguese man-of-war. The man-of-war is actually hundreds of tiny individual parts grouped for different functions. Its delicate, gas-filled float rises above the waves, its crest catching the wind like the sail on a ship. Beneath the float, long, stinging tentacles—used to paralyse fish and other animals that the man-of-war eats—trail down into the water. Other floaters include a species of snail that produces a raft of frothy bubbles on which it floats over the sea.

DRIFTERS

The drifters live in the sunlit surface waters, carried along at the mercy of waves and currents. Grouped together under the term *plankton*—from the Greek word meaning "to drift"—drifting life includes both plants, or phytoplankton, and animals, or zooplankton. Some animals like jellyfish and many tiny shrimplike and wormlike creatures spend their whole lives drifting in the upper layers of the sea. Others, such as certain fish, crabs, barnacles, sea urchins and starfish spend only the early part of their lives drifting passively as plankton and the rest as adults either swimming freely or living on the bottom. This immature period before adulthood is called the *larval* stage; animals going through it are known as *larvae*.

Some drifters are capable of making small movements and travelling down from the surface to certain depths, but they are powerless against horizontal water movements. Drifters do not sink because their bodies either contain globules of oil that act as floats, or have outside spines or hairs that provide friction and help prevent them from sinking.

A variety of microscopic plants seen under a microscope (above). Most life that is found in the sea depends on such phytoplankton.

Like tiny blue sailboats, the crested floats of three Portuguese men-of-war have been blown by the wind against a sea-wall. Below, two fragile, blue-shelled snails (*Janthina*) hang from their floating bubble rafts.

SWIMMERS

Animals that can swim are free to roam the open waters. Except for squid, the swimmers are largely animals with backbones—fish and marine mammals like whales, porpoises and seals—that are large and strong enough to move independently of the currents. They cut cleanly through the water with their streamlined bodies, using powerful muscles and propelling organs. Often they have a special swim bladder to keep them from sinking involuntarily. Air-breathing swimmers, such as whales, must surface for air, but they are equipped with highly compressible chests and lungs as well as special blood vessels to permit them to spend long periods in the depths.

With a strong sweep of its tail fin, an Indonesian carp (*Puntius gonionotus*) swings its streamlined body in a right turn.

BOTTOM DWELLERS

Most of the animals in the ocean are either attached to the bottom or live in shallow depths of less than 200 metres. Those permanently attached include sponges, corals and barnacles, all firmly secured to rocks and other objects on the shoreline or sea bed—and even, occasionally, to objects floating in the water. Certain marine worms live in tubes fixed to the bottom. Sea anemones, looking deceptively like underwater flowering plants, are examples of animals attached to the bottom that nonetheless can slide along or burrow into the sea bed to find a more favourable location.

Other bottom dwellers are able to move more freely. Flatfish can swim, and animals like octopuses, crabs and shrimps have legs for walking. Clams and certain marine worms also move about or burrow into the sand. One interesting fish, the mudskipper, has evolved a round sucker on its underside that it uses to cling to surfaces on the sea bottom and on rocks and trees above the water.

The red spider crab (*Schizophrys aspera*) walks along the bottom about 10 metres down in the Pacific.

Sea anemones in a variety of colours carpet the ocean floor.

The mudskipper is a bottom-dwelling fish with a circular sucker formed by the fusion of pelvic fins.

GETTING AROUND IN THE WATER

Beneath the water's surface is an active world. Animals are in motion everywhere—swimming, floating, drifting, moving through tunnels, burrowing, walking, crawling, pulling themselves over rocks. And the structures they use for movement are as varied as the movements themselves: legs, fins, feet, paddles, suckers; tiny, beating hairs called *cilia;* and small, whiplike appendages called *flagella*.

Small animals like free-floating flatworms glide over plants and rocks on cilia, while sea slugs slide forward by contracting the muscles that run up and down a flattened solelike undersurface. Starfish have stalklike tube feet lining the grooved underside of their arms. Ending in tiny suckers, these feet are in slow but constant motion, extending out searchingly and contracting again to move the animal along the bottom. Clams burrow through mud or sand by pushing a pointed foot into the soft bottom, whereupon the tip of the foot expands, anchoring the clam. The shellfish then contracts the extended foot and thereby pulls itself to a new position.

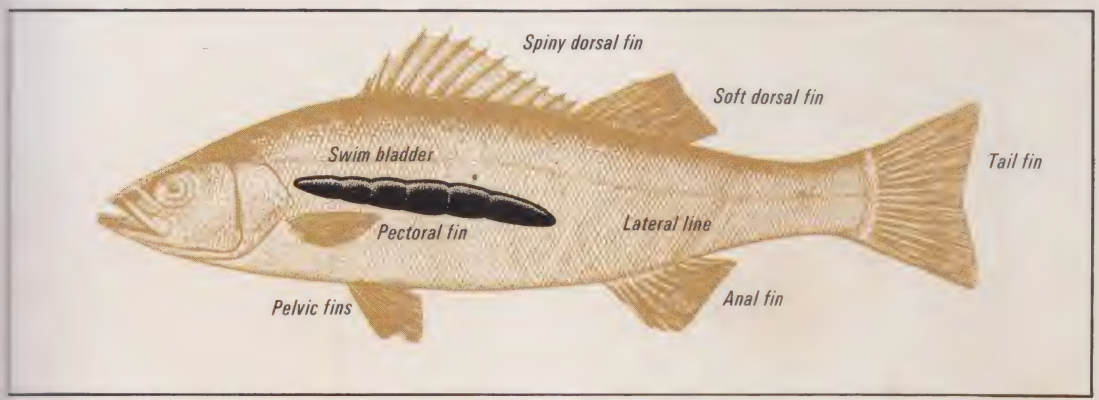
Other animals have bodies constructed to aid movement in equally remarkable ways. Spiny sea urchins use their spines as levers while pulling themselves along the bottom with tiny tube feet. Fish have streamlined bodies that offer little resistance to water, as well as fins for moving through the water, changing direction and for braking. Some, like the flying fish, sport expanding, winglike fins that allow them to leave and glide over the water for short distances. Lobsters and prawns, heavier than water, must walk on the bottom, but they can also propel themselves quickly backward by suddenly flicking their abdomens. Squid can swim by using their fins, but like octopuses they can shoot backward to escape enemies by a similar method of squirting a stream of water out of their bodies through a siphon. Jellyfish move in the same manner, contracting the edge of the bell-shaped body to squirt out water in order to move forward. Scallops also use the force of water to swim by snapping tight the valves of their hinged shells, producing jets of water to propel themselves in various directions.

HOW A FISH SWIMS

A typical fish swims in wavy movements, snaking from left to right as it pushes the water aside. Its body is beautifully streamlined for moving through water, with the head usually blunter than the tail and the thickest part of the body located about one third of the distance from the front. Most of the propelling force comes from the fish's body muscles and acts through the tail fin. The fish's slimy coating further cuts down its resistance to the water.

Fins are movable and are used for swimming, balancing, steering and braking. While the tail fin steers and propels, the dorsal fin (or fins) on the fish's back keeps the fish from rolling from side to side. The paired pectoral fins, one on each side of the body behind the gills, work with the dorsals to maintain balance and are useful in making upward and downward movements. Together with the paired pelvic fins, the pectoral fins act as brakes, allowing the fish to come to a stop without altering its direction. Anal fins along the underside act with the dorsals to help the fish swim without twisting along its length.

Most fish that do not live on the bottom have airtight sacs called *swim bladders* (or *gas bladders*) which contain gas taken from the bloodstream. These bladders regulate the amount of gas the fish needs to stay at a certain level, ensuring that the fish neither sinks nor floats to the surface. This is why most fish are found in the sea's middle layers and are neither floaters nor bottom dwellers. Certain fish that lack swim bladders, or have only small ones, must keep in constant motion to avoid sinking to the bottom.

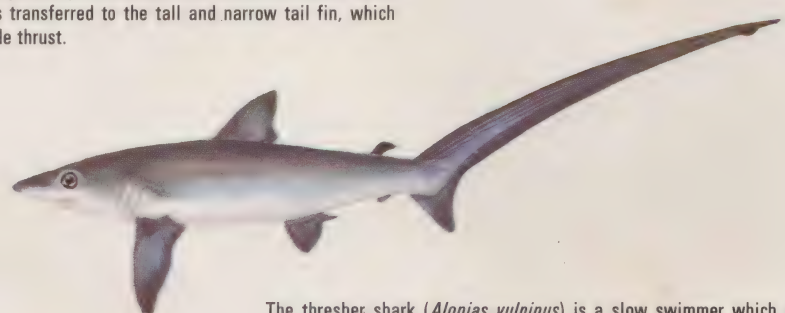


A typical fish showing the fins and the position of the swim bladder. Single fins along the top or bottom of the body are known as median fins; the pelvic and pectorals are called paired fins since there are two of each.

Bottom-dwelling fish like this frogfish (*Antennarius tridens*) are slightly heavier than water and are feeble swimmers. But they are able to walk along the bottom or clamber about on seaweeds with their limblike pelvic fins.

Eel-shaped fish like this quillfish (*Xiphasia setifer*) are inefficient swimmers; the forward thrust on the fins is evenly distributed throughout their bodies, making them sluggish in the water.

Tunnies like this yellowfin (*Thynnus albacares*) are the strongest swimmers among fish. Their bodies are perfectly streamlined, and almost the whole force produced by their muscles is transferred to the tall and narrow tail fin, which acts like a propellor to provide thrust.



The thresher shark (*Alopias vulpinus*) is a slow swimmer which must keep swimming to stay afloat since it is heavier than water.

A fish swims with a snakelike motion, pushing the water aside with the head to the left and right. The drawing shows one stroke of the body.

SENSE ORGANS

Underwater animals are made aware of changing conditions in their environment by various sense organs. Many animals without backbones have only very simple 'eyes' consisting of one or more light-sensitive cells; others have light-sensitive bodies with no visible eyes. Such animals can tell only whether light is present or absent, enough to allow them to find a comfortable level of light or shade. Planarian flatworms (see page 35) have black pigmentation in two eye bowls, which receive light and send messages to the brain. Sharper eyesight is found in certain crustaceans with eyes on stalks, and some scallops have as many as a hundred little eyes shining like diamonds along the edge of their fleshy mantles. The keenest sight among animals lacking backbones is found in squid and octopuses, which have eyes that are remarkably like human ones, complete with pupil, iris and lens.

Other sense organs of animals without backbones include touch cells and chemical receptors, often found in hairs or bristles and in tentacles. Crabs, shrimps and other crustaceans have nerve endings sensitive to water flow and chemicals as well as a sense of touch located in the antennae. In jellyfish and crustaceans, there are small, round structures containing granules of chalky matter that tell the animal when it is off balance so that it can right itself.

The most complex assortment of sense organs is found in animals with backbones. Fish have eyes, nostrils, organs for hearing and a sense of touch found in the skin. They have taste buds on the head, body, tail or—in certain species—on whisker-like *barbels*. Fish also have a unique pressure sense organ called the *lateral line*, that appears along each side of the body. The lateral line receives low-frequency vibrations and pressure waves which the fish hears and feels, giving it a good sense of its surroundings and enabling it to avoid danger and find food that is hard to see.

Some fish "feel" their environment through a sense that is sensitive to electric fields. The mormyrid fish compensates for poor eyesight with paired electric organs in its tail that create a continuous electric field around its body. Changes in this field signal the presence of objects, thus helping the fish to find its way in murky water.

The sensitive eye of the octopus forms images through a lens and a highly advanced retina. The yellow object is the animal's siphon.

With its eyes on stalks that look like periscopes, the ghost crab is able to quickly detect both enemy and prey.

The scallop *Chlamys* has many small eyes on the edge of its mantle.

The dotted lateral line extends along the side of this carp. It is the organ that keeps a fish in an aquarium from bumping into the sides.

The head of this fish (*Labeo*) bristles with sense organs. The whisker-like barbels are used for feeding and tasting, and the small, whitish dots form part of the lateral-line sensory system that detects vibrations. Also visible are two nostrils and an eye.

RESPIRATION

Like us, underwater animals must take in oxygen to survive. Whales, seals, turtles and certain other aquatic animals extract oxygen from the air with their lungs, where it flows into a system of tubes and air sacs and out again. However, many underwater animals—certain worms, the larger crustaceans, most molluscs and almost all fish—extract oxygen from water by means of gills. In fish, water is taken into the mouth, passed through gill chambers containing blood-rich *gill filaments* to extract oxygen and finally expelled through openings in the sides of the head. A large amount of water must pass over the gills of the active animal for it to be able to receive a sufficient supply of oxygen. This is because the amount of dissolved oxygen in water is quite small compared to the amount in air. Thus while an air-breathing animal may use a little of the oxygen taken in at each breath, an animal breathing through gills uses almost all the oxygen in the water taken in. Food is prevented from entering the gill chambers by *gill rakers,* small projections attached to hoop-like structures called *gill arches* inside the mouth. Covering the gill chamber is a bony shield, known as the *gill cover,* that protects the sensitive *gill filaments,* whose proper functioning enable the fish to survive.

Some fish have adapted to breathing air when there is a poor oxygen supply in the water, a situation often caused by pollution as well as natural ecological imbalances. The common carp does this by taking in an air bubble and holding it in its mouth near the gills. Other fish, such as lungfish and mudskippers, have lunglike structures that allow them to breathe air when oxygen becomes scarce. The mudskipper's gill filaments are short and stiff and do not collapse in the air, allowing it to live out of water at low tide.

This mudskipper (*Boleophthalmus boddaerti*) has, by means of special bones, inflated its gill chambers with water, air or a mixture of both.

The 10 external gills of this colourful sea slug protrude like a red tuft from the rear end of the animal's body, as it crawls upside down along the water surface.

WHY FISH DIE OUT OF WATER

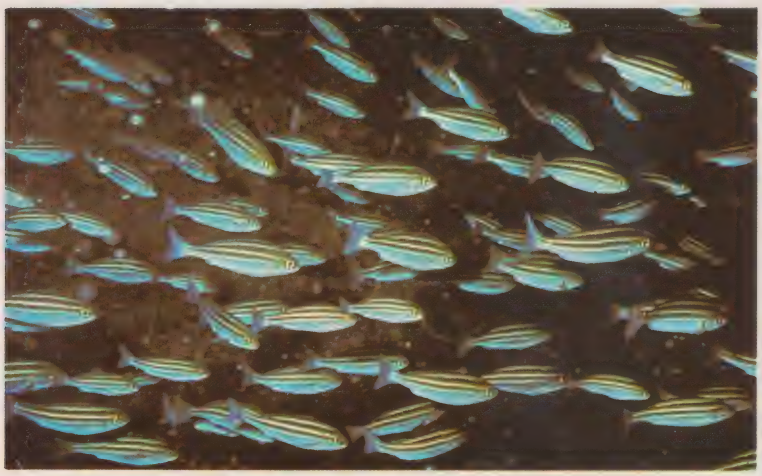
Being specialised for living in the water, a fish's gills are weightless in water and are arranged in plates that float separately, enabling the fish to absorb oxygen. When a fish is taken out of the water, however, it soon dies. This is because the gill plates become matted together, leaving insufficient gill surface to absorb all the oxygen necessary for the fish to live, even though air contains more oxygen than water.

The gills of a bony fish can be clearly seen in these two pictures of a coral trout (*Plectropoma maculatum*). At right, the fish opens its gill covers to allow a small fish called the cleaner wrasse to remove parasites, thus exposing four of its five gill arches and the red gill filaments. At left, the wrasse continues the job by cleaning inside the trout's wide-open mouth where the teethlike gill rakers and a food passage that leads to the trout's digestive organs are exposed to the camera.

SHOALING

A special kind of behaviour known as *schooling* or *shoaling* occurs in about 4,000 species of fish, each species regularly swimming together in groups called *schools* or *shoals*. A shoal is a fish society in which each member affects the others, and the whole group sometimes behaves like a single huge fish. Swimming at fixed distances from one another on parallel course within the shoal, there are almost equal numbers of fish from front to back, side to side, and top to bottom. They keep a regimented formation that may tighten, disperse and form together again with great precision. Although fish of different sizes and even different species may be found in certain shoals, most shoals are made up of fish of the same species and size. Vision is probably the most important of the senses in keeping a shoal together, since shoals often break up at night. But the lateral line sense organs also seem to aid in making fish aware of each other's movements and positions, since herring stay in shoals at night and blind fish are found in certain shoals.

Swimming in a shoal has many advantages. The members work together to secure food, and finding a mate is relatively easy. The shoal also provides protection. Members of a shoal usually follow the fish swimming in front, but if one side of the shoal is threatened, the whole shoal will turn away, influenced by those closest to the danger. And since shoaling fish rarely have bright or colourful markings, enemies are confused by a mass of moving lines or glittering shapes and find it difficult to focus on one fish. Even if an enemy successfully attacks a shoal, it can eat only a limited number of fish.



A shoal of sweetlips swims freely in the upper regions of the ocean.

Fish in a shoal swim in tight formation on a parallel course.

A large shoal of silversides. The fish keep an equal distance from one another and in a confined space may circle for hours.

FOOD AND FEEDING

One of the major activities going on underwater is eating. At the beginning of a long chain of eating and being eaten—called the *food chain*—are plankton, trillions and trillions of tiny plants and animals upon which most other life in the water ultimately depends. These tiny creatures are eaten by other organisms such as tiny shrimplike creatures called *copepods*. Copepods are themselves eaten by larger animals such as herring, which are eaten in turn by still larger animals like mackerel and cod and so on. At one end of the chain are huge numbers of tiny animals that reproduce easily and abundantly and eat enormous amounts of food; at the other end are a few large meat-eaters that reproduce a few at a time and require only a small percentage of their body weight each day as food.

Certain animals cannot move about to search for food since they are attached to some object; others wait for food to come to them even though they are capable of some movement. Many of these fixed feeders can survive only because sea water containing plankton circulates, bringing their food to them. Filter-feeding clams siphon water and the micro-organisms in it into their shells, thus trapping their food. Other fixed feeders, however, rely on deadly devices to gather food. The delicate, sticky tentacles which fringe the mouths of sea cucumbers trap small particles of food which are then transferred to their mouths. The stinging tentacles of sea anemones reach out to paralyse and kill passing prey.

Free-moving animals either prey on fixed feeders or actively pursue moving animals using various means to catch and trap them. Some starfish tug open the shells of clams and scallops, while octopuses subdue their victims with strong suckers on their tentacles. Jellyfish, sea anemones and corals use tentacles to sting and capture prey.

REPRODUCTION

Since all animals eventually die, reproduction is essential for the survival of the species, and in underwater animals it occurs in a variety of ways. The simplest form—seen in the amoeba—is a process of division. The amoeba merely splits into two, thus creating two identical amoebas from one. Another process is called *budding* and is found in certain hydroids. These hydroids produce a little budlike outgrowth from their bodies that develops into a miniature adult and finally breaks free to live independently. Other animals such as corals also reproduce in this way, but the new and old adults remain connected to each other to form enormous linked colonies. Some marine worms bud off a succession of young individuals from the tail end which are coupled one behind the other like links in a chain, dropping off one by one as they grow in size.

The creation of most new marine animals, however, occurs through *sexual reproduction:* the union of egg cells and sperm cells. The sperm cells fertilise the egg cells, meaning that they unite with them so that the development process can begin. In some cases both eggs and sperm are produced in the same animal, called a *hermaphrodite.*

American seahorse (*Hippocampus hudsonius*) is born from its father's pouch.

A brightly coloured female sea slug releasing its eggs.

A female octopus crawls into a hiding place with her eggs.

Amongst aquatic animals fertilisation generally occurs outside the female's body and is therefore referred to as *external fertilisation.* The female first sheds her eggs, which are then fertilised by sperm cells released over them by the male. Since the chances for fertilisation and survival of each egg may be very small, animals usually release enormous quantities of eggs and sperm. Exposed to the changing water world, the fertilised eggs may be protected by a glutinous jelly and attached to a rock or hidden in a safe place until the tiny larvae, called *fry,* are born. Certain animals go through a prolonged larval stage, floating in the water until they emerge in their adult form.

Internal fertilisation is reproduction in which the eggs are fertilised by sperm directly introduced into the female's body by a specially developed male organ. Such a process means that the eggs have a better chance of being fertilised effectively, and thus the female produces fewer eggs. There is also a surer chance of successful birth since the fertilised eggs usually develop to a certain extent before they are released to the outside. Certain fish, known as *live bearers,* never have to release eggs—the fry develops completely inside the female and emerges as a live, fully formed animal.

The male forehead breeder (*Kurtus indicus*) carries the eggs in a bunch on its forehead, held by the modified first ray of the dorsal fin.

A North Pacific surfperch (*Neoditrema temmincki*) giving birth to live fry.

The Egyptian mouthbreeder (*Haplochromis multicolor*) holds the fertilised eggs in its mouth (left) until they hatch and the fry leave their sanctuary (above).

COURTSHIP AND PARENTAL CARE

Reproduction among fish generally takes place during a special breeding season when the conditions of the environment—temperature, currents and food supply—are favourable for mating. Before mating, males and females gather together and often engage in courtship. Usually the male tries to attract the female by moving his body in a kind of dance or by displaying brilliant colours and bold patterns. This behaviour stimulates the female—either to release her eggs, whereupon the male fertilises them with a discharge of sperm, or, in internal fertilisation, to allow the male to unite with her.

After mating most fish simply leave their eggs without further care, but there are some species that prepare special nesting sites and jealously guard both eggs and young fry like anxious parents. Fish that give birth to live young may take great care of them, although most of the crucial care has taken place within the female's body.

Sticklebacks are well known for their characteristic mating behaviour and care of the young. During the mating season, the male builds an elaborate nest by cementing together pieces of plant material with mucus produced by his kidneys. He then zigzags in a courtship dance, coaxing and driving a succession of females into his nest, sometimes hurrying them by nipping their tails. After the eggs are laid, the male guards them until they hatch. Some fish even make a "nest" in other animals. The female bitterling deposits her eggs inside the shell of a freshwater mussel through a long tube. The male then sheds sperm that is drawn inside with water as the mussel breathes. As the young bitterlings hatch, the mussel throws out its own larvae, which attach themselves for a time to bitterlings as parasites.

In several species the male protects the eggs or young fry by swimming over them or by holding them in a safe place. The male mouthbreeder scoops up the eggs he has fertilised and keeps them in his mouth until they hatch. Even after the fry have hatched the male will continue to give them a place of refuge whenever they are threatened with danger. The male seahorse has a special pouch in which the female's eggs are laid. They then develop there.

A male 15-spined stickleback chases a female into the nest in a zigzag courtship dance.

After fixing them to a rock in the stream, a Japanese sculpin guards its eggs.

The female bitterling deposits her eggs inside the shell of a freshwater mussel.

LIFE CYCLE OF THE SALMON

Salmon reproduction takes place only after a remarkable journey that is a testament to animal instinct. Born in shallow streams, young salmon swim downriver to spend most of their adult lives in the open sea. But when spawning time draws near, the salmon fight their way back upstream, often leaping through violent rapids and over waterfalls, to reproduce and often to die in the same streams that gave them birth. Some manage to go back to sea.

Directed to the river of their birth by smell, adult salmon begin the difficult journey upstream to the spawning grounds.

Straining against the swift current, a salmon leaps through rapids.

Mouths open wide as they labour, salmon reproduce in a river bed. The female (centre) lays the eggs in a shallow pit she has prepared and the male (right) fertilises them. At left is the sperm released into the water and a second male who lost a fight over the female.

Fertilised eggs (top left) have quite a large yolk, and as they develop the eyes and blood vessels of the embryo are clearly visible (top right). Soon the head becomes distinct (bottom left). The eggs hatch after about 60 days, but the yolk sac remains attached to nourish the fry as they begin to swim around (bottom right).

Fry with large yolk sacs a week after hatching. The yolk is gradually consumed and the sac begins to disappear. At one month the sac will be completely gone, and the fry will be able to feed independently.

At three months the fry can swim freely in the river.

Young salmon begin their journey downstream to a new life in the sea.

SYMBIOSIS, MUTUALISM AND PARASITISM

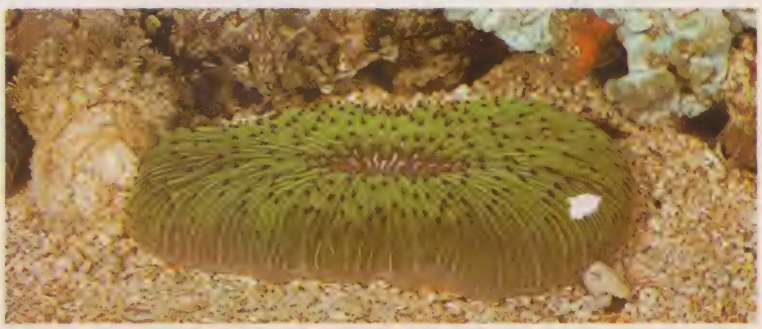
Animals share important relationships with other animals and plants. When two organisms are almost always found living together, we call this relationship *symbiosis*. *Parasitism* is a form of symbiosis which occurs when only one partner, the parasite, benefits from the relationship. Fish suffer from external parasites such as lice, which stick to their gills and suck blood, as well as internal parasites like worms that live their whole lives inside their bodies. While parasites can be deadly to the host animal, the most efficient parasite causes minimum damage, for if it kills its host, it has the serious problem of finding a new one.

When both partners profit by living together, we call the relationship *mutualism*. The clownfish, for instance, shares its food with the sea anemone, among whose tentacles it takes refuge, and it also probably lures other fish to its host with its bright colours. The sea anemone in return seems to remove small parasites from the clownfish's body and protects it from enemies with its stinging tentacles—poisonous to other fish but not to the clownfish.

Some fish—like the coral trout at the bottom of page 17—strike a certain posture or go to "cleaning stations" to have cleaning fish such as wrasses remove the parasites and bacteria on their gills and bodies. Without this grooming they might eventually die of parasitism. Some animals and plants live in such close partnership that each would not be able to survive without the other. Such a relationship exists between certain corals and algae. The carbon dioxide of the coral is used by the algae to make sugars and oxygen, essential elements in the coral's survival.

Mutualism between sea anemones and a hermit crab. As the crab moves around, the anemones attached to its shell are carried to new sources of food. The crab gains a disguise and is protected from enemies by the anemone's tentacles.

Protected by the long tentacles of a purple sea anemone, a small black colony of moss animals lives on a sandy sea bottom.



This mushroom coral of the Indo-Pacific (*Fungia*) gets its brilliant green colour from the tiny algae that live in its tissues. Neither the coral nor the algae could survive alone.

A cleaner prawn (*Parasicyonium*) living among the tentacles of a sea anemone. In return for keeping the anemone clean, the prawn receives protection and a sure source of food.

Two small clownfish take refuge among the tentacles of a sea anemone. Large crustacean parasites attached to the clownfish suck the juices of the fish without killing them.

CAMOUFLAGE

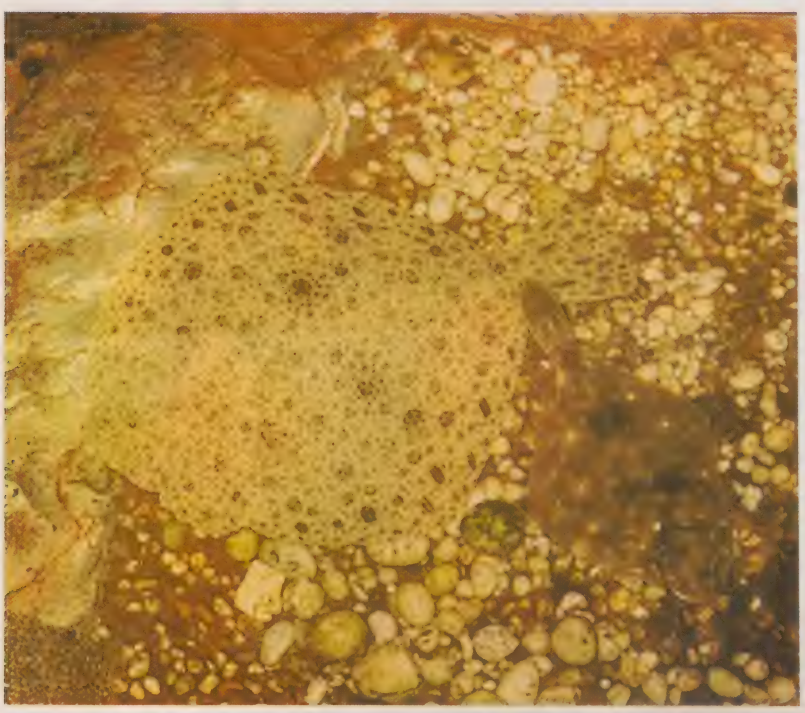
Animals need to be easily recognised when they are courting a mate, proclaiming their territory or trying to persuade an enemy that they are not good to eat. In the struggle to survive, however, there are times when animals benefit from not being seen at all. They thus try to disguise, or camouflage, themselves. Camouflage is used both to secure food and to prevent being eaten. It is an advantage for the hunter—especially if it can move only very slowly—to be able to disguise itself in order to make surprise attacks on unsuspecting prey. The prey, on the other hand, uses camouflage to fool or hide from the hunter.

Animals camouflage themselves in various ways. Some hide in mud, sand or stones or among plants and other animals, often exhibiting colours or markings that match those of their surroundings. Others present patterns that serve to break up the familiar shape of their bodies to fool their enemies. Certain animals are even able to change colour to blend with their backgrounds. This is done by altering the arrangement of microscopic granules of pigment within specialised cells in the skin. Some species of flatfish can change not only their colours but also the patterns of their skins to imitate the bottom.

Waiting ominously for its prey, the colour and markings of this flathead (*Platycephalus*) make it hard to distinguish from the gravel bottom of an East African shore.

This anemone shrimp (*Periclimenes brevicarpalis*), well disguised among the coral in the centre of the picture, has a unique form of camouflage: Except for a few disconnected spots that appear here as patches of black. white and gold and mark the locations of vital organs, the animal is as transparent as glass.

Looking more like an insignificant piece of ocean bottom than a live animal, this Indo-Pacific anglerfish (*Lophiomus setigerus*) lies in wait for a meal.



A thick black line seems to divide this Pacific angelfish (*Holacanthus arcuatus*) into two deceptive shapes, neither of which looks like a fish.

Hardly recognisable as fish, two species of European flatfish, the plaice (*Pleuronectes platessa*), left and the brill (*Scophthalmus rhombus*), far left, have changed their colours and skin patterns to imitate the rocky bottom on which they lie.

AGGRESSION AND DEFENCE

In the underwater world, staying alive is a constant struggle. Animals are frequently forced to defend themselves by shoaling, camouflage, or with special protective devices such as spines, teeth, claws, tentacles and body armour. Often male animals solve the problems of competing for food and ensuring the safety of their young by claiming and defending their own territories, usually against other males of the same species. This is called *territorial behaviour*. Such males often have bright and distinctive colours which they show aggressively in a *threat display* designed to warn other males to keep away and to invite females to approach. Frequently the display involves some threatening movement; fiddler crabs, for example, wave a menacing claw in the air to intimidate an intruder or a possible rival.

Fights between males take place at the border between territories, but they generally do not lead to serious damage, since the loser usually retreats. Siamese fighting fish, however, are famous for their vicious behaviour when defending their nests. If two males are put in a closed space where the loser cannot flee, they may fight to the death.

This male mudskipper (*Scartelaos viridis*) engages in threat display out of the water by standing up in the mud on its tail and spreading its fins.

Two male gobies threaten each other by opening their mouths wide during a fight over territory.

In a violent fight over a nesting site on the river bottom, a male salmon bites a rival male.

Waving a huge claw in the air, this male fiddler crab (*Uca annulipes*) warns other males to keep away.

Two male fiddler crabs fight in the territory between their burrows. The loser will retreat, sometimes without one of his claws.

RELATIVES IN THE WATERS

The animal world is divided into about 20 major groups. Each group, or phylum, includes animals whose bodies show certain basic similarities and also certain structural features that distinguish them from all other kinds of animals.

Except for three phyla—comb jellies, moss animals and lamp shells—the groups are arranged in logical sequence, starting with the single-celled protozoans at the left, and leading to the most advanced group, animals with backbones like fish and whales (right, facing page). Only the principal groups —illustrated with examples of each—are shown in the illustration above.

1. Paramecium
2. Euglena
3. Amoeba
4–7. Other protozoans
8. Portuguese-man-of-war
9. Jellyfish
10. Sea anemone
11. Corals
12. Sea wasp
13. Hydra
14. Sponges
15. Comb jelly
16. Marine flatworm
17. Parasitic flatworm
18. Freshwater flatworm
19. Scale worm
20. Bristleworm

1. Fanworm
2. Freshwater leech
3. Parasitic roundworm
4. Moss animal
5. Copepod
6. Horseshoe crab
7. Crab
8. Prawn
9. Lobster
30. Hermit crab
31. Barnacle
32. Arrow worm
33. Lamp shell *Lingula*
34. Lamp shell
35. Tusk shell
36. Chiton
37. Scallop
38. Marine snail
39. Squid
40. Octopus
41. Nautilus
42. Starfish
43. Brittle star
44. Basket star
45. Sea cucumber
46. Sea urchin
47/8. Feather stars
49. Sea squirt
50. Lancelet
51. Sea-squirt tadpole
52. Crocodile
53. Shark
54. Flying fish
55. Salmon
56. Marine turtle
57. Frog
58. Salamander
59. Sea snake
60. Duck
61. Seal
62. Sea cow
63. Penguin
64. Whale

SIMPLE ANIMALS

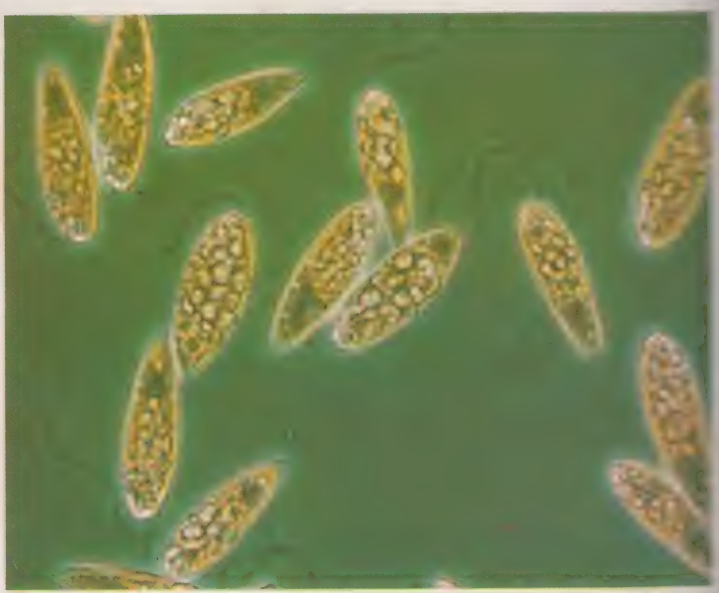
The animal kingdom can be divided most simply into two parts: the invertebrates, or animals without backbones, and the vertebrates, which do have backbones. Both of the two major groups are found in the world's waters. Invertebrates come in many different sizes and shapes, from the simplest single-celled protozoans to the larger and more complex crabs, molluscs and starfish. Invertebrates account for 90% of living animal species, though many are hardly noticed by humans or can be seen only under a microscope.

Amoeba proteus, an undefined blob of protoplasm, lives on the bottom of ponds. It moves by forming feetlike bulges that flow forward—the most primitive form of animal locomotion. Any part of its surface can swallow tiny food particles.

PROTOZOANS

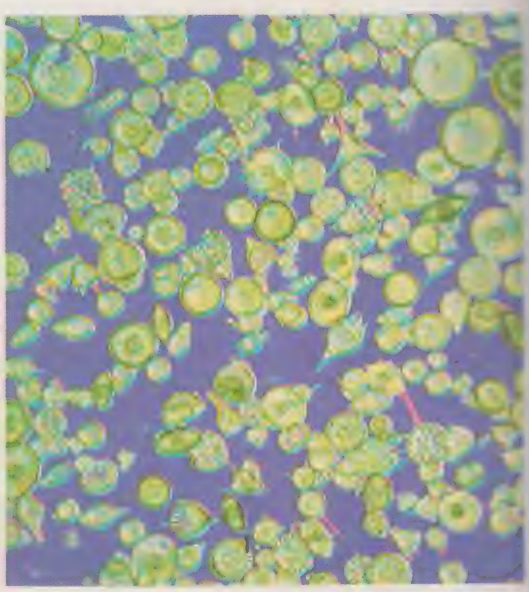
The protozoans are the simplest of all living animals and may resemble the first living creatures on earth. Found in both fresh and salt water they form a diverse group of microscopic, single-celled creatures. Most can be seen only under a microscope. Protozoans are composed of a complex, jelly-like material called *protoplasm*. Some, like the amoeba, have shapeless bodies of unprotected protoplasm; others construct delicate shells or skeletons around the protoplasm, which gives their bodies a definite shape. The single cell of the protozoan carries out all the functions necessary to life. The nucleus is responsible for reproduction—often by simply splitting to form two animals—and carrying on inherited characteristics; other parts of the cell take care of feeding, waste elimination and protection. Many protozoans possess cilia which they use for locomotion. Others have flagella to push through the water and pull in food. Since, like green plants, some protozoans contain chlorophyll, which allows them to use the energy of the sun to produce food, it is not possible to place these creatures in the category of plants or animals.

Protozoans form the greatest part of the mass of living things in the sea and standing at the beginning of the food chain—they are the most important source of food for marine animals. But protozoans are also destructive: as parasites of plants and animals they give rise to diseases, including malaria and amoebic dysentery in humans. Even in death, protozoans are important. The microscopic skeletons of certain species like radiolarians and foraminifers slowly sink to the ocean depths to form enormous deposits. Over long periods of time these deposits are transformed into rock.



Euglena is a small, freshwater protozoan that shows both plant- and animal-like characteristics. Possessing chlorophyll and feeding like typical green plants, it is nonetheless capable of active movement, an attribute of animals. The whip-like flagella at the front end of its body pulls the protozoan through the water with movements similar to those of a corkscrew.

The freshwater protozoan *Paramecium* moves through the water by beating the tiny cilia that surround its body in such a way as to cause the animal to revolve continually, describing a spiral path. More complicated than the amoeba, the *Paramecium* has a stiff outer "skin" of protoplasm which gives the animal permanent shape. The large grey oval at the left is the nucleus.



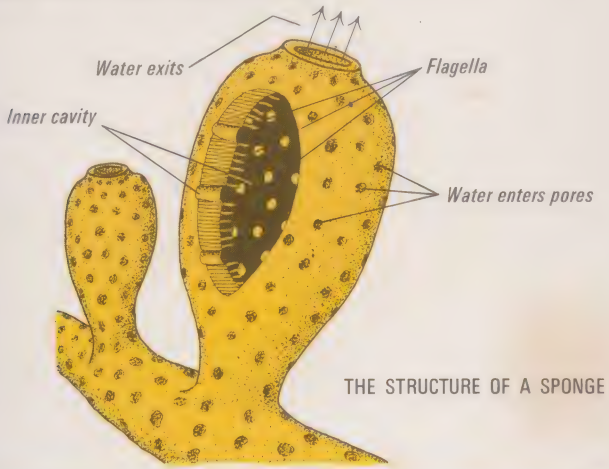
Radiolarians are protozoans with hard skeletons. These skeletons sink to the sea bottom to form deposits that may ultimately become flint after complex chemical processes take place.

SPONGES

Sponges *(Porifera)* are very simple marine animals that live attached to the bottom or to other objects. Most live in the sea, mainly in shallow water, but there are some freshwater species. Though sponges have bodies composed of many cells, putting them on a higher level of organisation than protozoans, the cells are merely joined together loosely in a simple construction. Some species have fibrous skeletons and a soft, porous texture: these are the animals used to make commercial bath sponges, once in great demand but now largely replaced by synthetic varieties. Others have hard skeletons made of chalky or glassy, needle-like structures called *spicules* that may be united into a continuous network; one of the most beautiful is the lace-like skeleton of the Venus flower basket, often a prized souvenir.

Sponges have no nervous systems, no true body tissues and no mouths. Numerous minute pores in the skin lead into an inner cavity lined with special cells bearing flagella. The flagella draw water through the pores into the cavity where the microscopic organisms on which sponges feed are extracted. The water exits through one or more large openings.

The body shapes of sponges are not only flat or tubular but often assume a compact, rounded shape. Sponges cling to rocks, seaweeds or corals or form large, tubular colonies rising from the sea bottom like pillars or small trees. The largest species is the Neptune's cup, which grows to almost two metres in diameter. Sponges are often brightly coloured since, apart from sea slugs, they have few enemies and thus little need to conceal themselves. They do, however, provide camouflage for other animals, most notably certain species of crabs that cover their bodies with living sponges.



THE STRUCTURE OF A SPONGE

Tetilla serica is a small sponge from the Northwest Pacific.

Callyspongia elegans is a sponge found on rocks at depths of 10 metres in Japan.

A sponge colony exposed at low tide on a Southeast Asian shore. The large outflow siphons can easily be seen.

A small fish hovers near the huge siphon of the Neptune's cup sponge.

Like lavender pillars, columns of tube sponges rise from a coral reef.

A colony of flat encrusting sponges covers areas of rock. Outflow siphons can be seen at the centre of each sponge.

A Venus flower basket (*Euplectella oweni*) of the Indo-Pacific. A portion of living sponge has been peeled away to reveal the animal's delicate skeleton and two tiny prawns—a female (blue) and a male—that spend their entire lives inside the sponge.

JELLYFISH AND OTHERS

JELLYFISH, ANEMONES AND CORALS

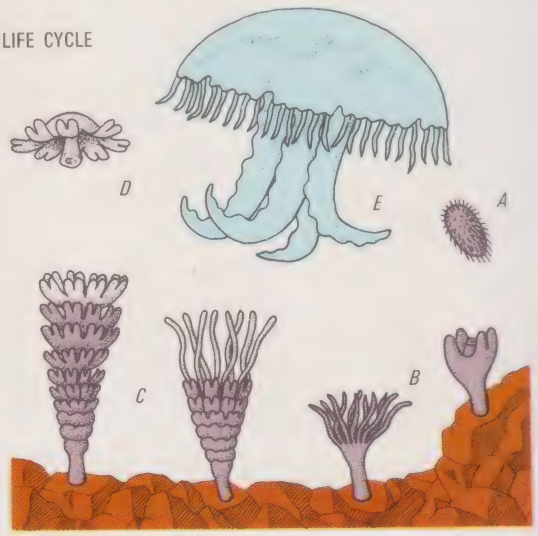
Jellyfish, anemones and corals are all *coelenterates,* simple animals found both as individuals and in colonies living primarily in the sea, though there are a few freshwater species. Many have larvae. Their bodies are organised around a centrally placed mouth leading into a hollow cavity or gut. A cylindrical body shape, characterised as *radial symmetry,* allows the animal to face its environment on all sides at the same time, ready to catch food or meet danger from any direction. Coelenterates possess a number of tentacles armed with *nematocysts,* minute stinging or nettle cells that catch and poison unwary prey. The nerve cells of coelenterates are not concentrated as in higher animals, but are spread out in a diffuse network.

POLYP AND MEDUSA

The two basic body forms of the coelenterates are called polyp and medusa. A polyp is an animal shaped like a short tube with closed ends. In the centre of one end is the mouth, surrounded by many tentacles. The opposite end is attached to a solid object such as a rock or plant. Polyps are found either as individuals or in colonies. The sea anemone is a single polyp, whereas most corals are made up of many polyps joined together. The medusa is a free-swimming creature with a jelly-like body shaped like a bell. Its mouth is found in the centre of its concave underside. The medusa swims by slow, rhythmic contractions of the muscles around its edge, propelled forward as water is forced from the bell. The best known medusa is the jellyfish. In the life cycle of many coelenterates both the polyp and medusa form may occur.

JELLYFISH

The most widely known coelenterates are the jellyfish *(Scyphozoa).* Although there is often a polyp stage in its development, the mature jellyfish is a medusa. The floating portion of the medusa can measure from 1.7mm. to 180cm. across depending on the species, and hanging from it can be anywhere from a few to hundreds of stinging tentacles. The jellyfish's internal organs are grouped symmetrically around the mouth in multiples of four. Its sense organs are sensitive to light and gravity and warn the animal when it becomes tilted.



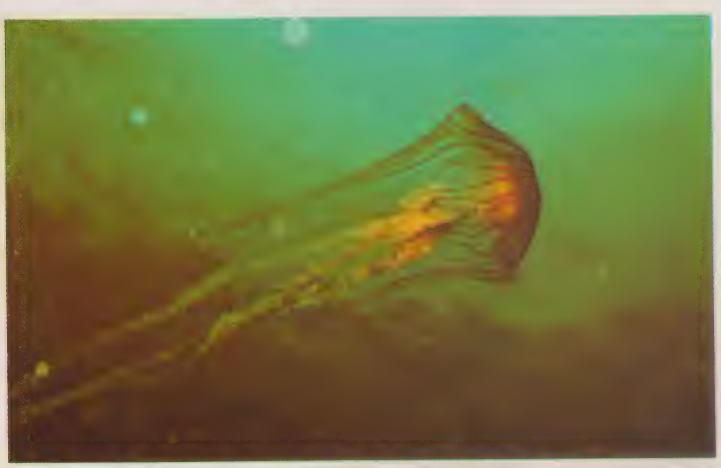
A larva (A) develops from the fertilised egg and swims by moving tiny cilia. It soon becomes a polyp (B), attaching itself to a solid object. The polyp develops segments (C) that separate (bud off) from the parent and swim away as tiny medusae (D). Each medusa grows into a jellyfish (E). The spawning of mature jellyfish produces a fertilised egg to start the cycle all over again.

Nematocysts are minute capsules found inside a single cell. Each capsule has a hollow thread wound up inside it. When a hair trigger is touched the thread turns inside out and shoots outward.

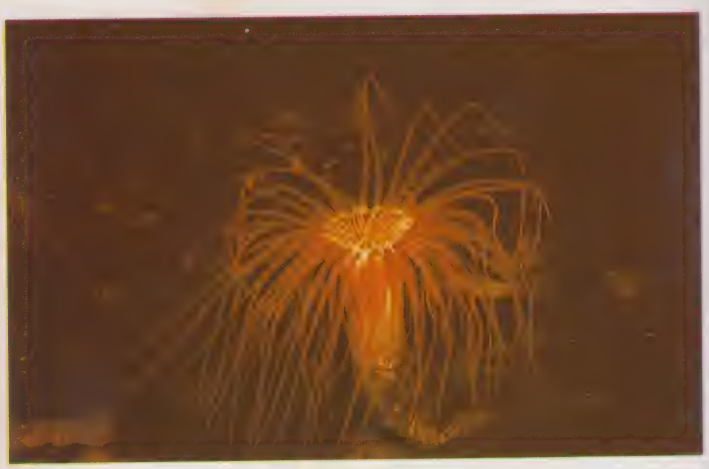
The common jellyfish (*Aurelia aurita*) lives in seas throughout the world.

The sea nettle (*Dactylometra pacifica*) gets its name from the fact that it stings like a plant called the stinging nettle.

The box jelly, or sea wasp (*Charybdea rastonii*), named for the shape of its bell. One species can kill a man.



Long tentacles trail from the bell of a jellyfish, a typical medusa.

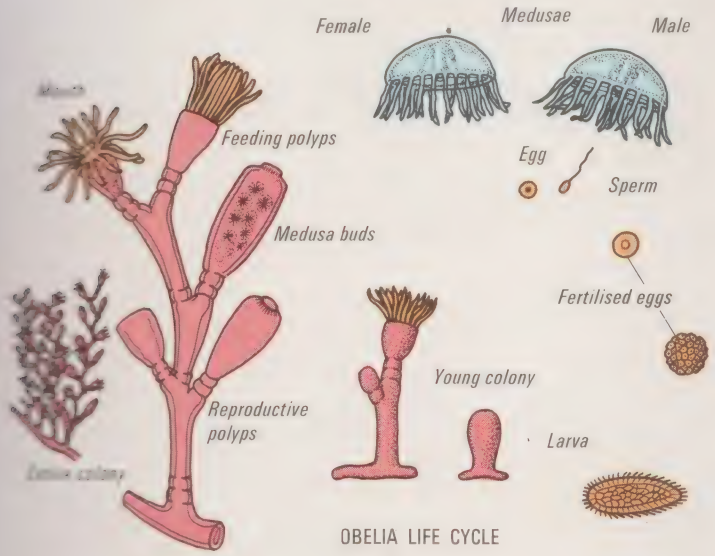


The sea anemone is a large polyp.

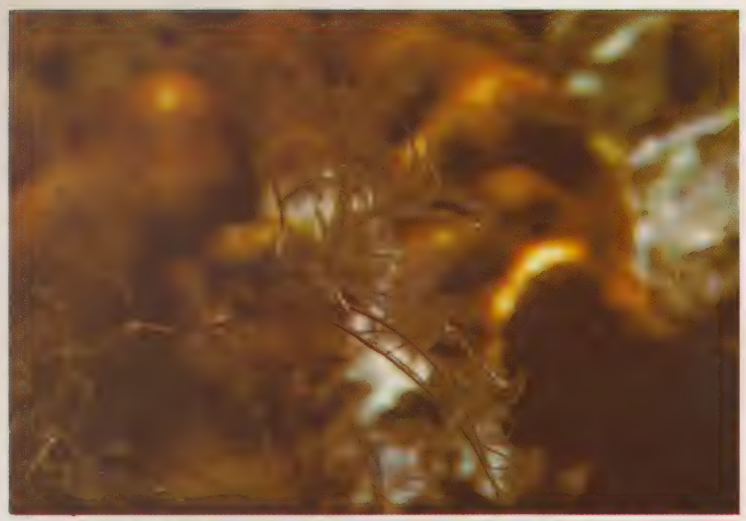
HYDROIDS

The hydroids *(Hydrozoa)* take more different forms than other major coelenterate groups—from tiny, solitary polyps and medusae to more complex colonies. They can be either fixed or free-floating. Though the polyp form is usually more visible than the medusa, the hydroids are the one group of coelenterates in which neither basic body form predominates. Hydroids are found in fresh water, but the vast majority are marine.

The illustration below depicts the life of a typical marine hydroid, Obelia. Obelia begins life as a single polyp that eventually grows into a colony of many polyps. Some polyps have a mouth and tentacles and perform a feeding function for the colony; others produce a number of buds that develop into medusae and are released into the water. The free-swimming medusae, capable of sexual reproduction, produce fertilised eggs that become larvae. The larvae finally settle down as polyps to start a new colony.



OBELIA LIFE CYCLE



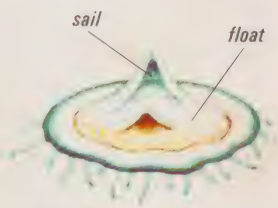
Each delicate feathery plume of the stinging hydroid (*Plumularia corrugata*) carries hundreds of tiny polyps and can deliver a painful sting. It is commonly found on coral reefs throughout the Indo-Pacific tropics.

FLOATING HYDROIDS

Floating hydroids *(Siphonophora)* float in the open sea by means of a gas-filled bag, or float, that projects above the water and often functions like a sail. They demonstrate the ability of component individuals (polyps and medusae) to exist in different forms. Every floating hydroid is really a colony made up of various kinds of polyps and medusae. Each kind carries out a particular function for the colony as a whole including swimming, digestion, stinging and budding off medusae for sexual reproduction. The most notorious floating hydroid is the Portuguese man-of-war. Trailing from the man-of-war's float are slender tentacles—sometimes as long as 50 metres—that carry nematocysts capable of delivering very painful stings to unwary swimmers.

Another floating hydroid, the amusingly named By-the-wind sailor, has a sail-like float that enables the animal to navigate at right angles to the wind and right itself when turned upside down by a wave.

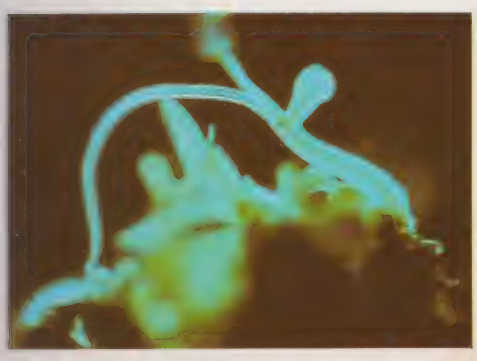
The Portuguese man-of-war (*Physalia*) is found in the waters of all warm seas.



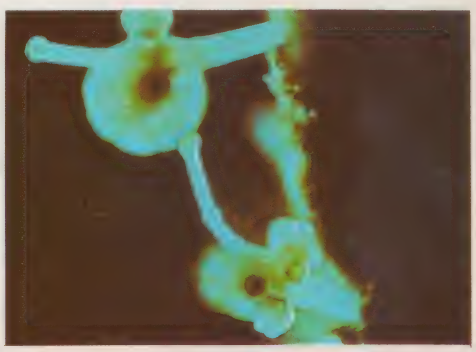
By-the-wind sailor (*Velella*) is a small animal found in warm seas. Its central mouth is surrounded by reproductive polyps, which are protected by stinging, grasping polyps.

THE BIRTH OF A HYDROID MEDUSA

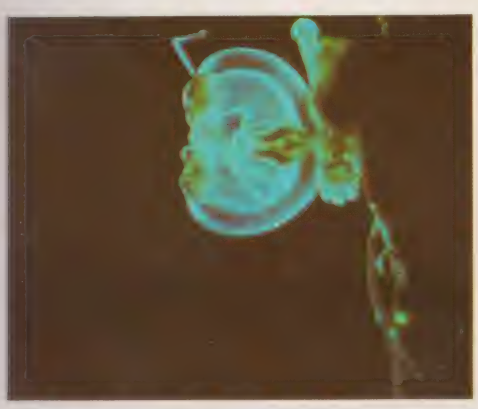
The hydroid *Proboscidactyla flavicirrata* which lives at the entrance of the tube of a certain tube-dwelling species of Japanese worm, produces a rootlike foot on which tiny medusae will grow and then bud off.



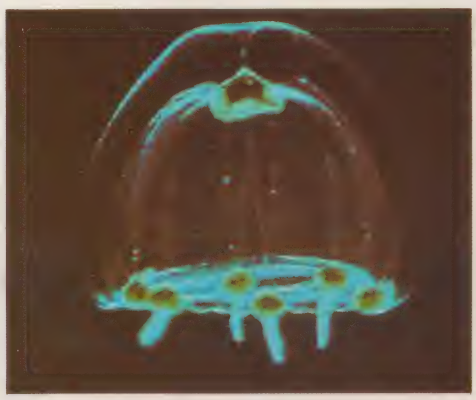
Medusa buds appear on the hydroid's rootlike foot.



The growing medusa.



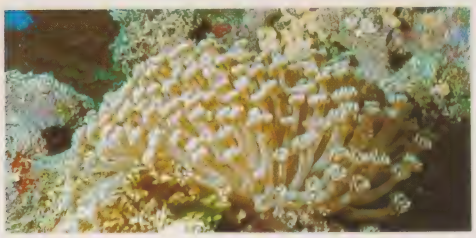
The familiar medusa form is clearly evident.



The matured medusa.

ANTHOZOA

Anthozoa or ''flower animals'' make up the largest group of coelenterates. Such animals have polyps but no medusae and only the larvae are free-swimming; the adult animal is anchored to the ocean floor. The gut cavity and tentacles are provided with nematocysts and the mouth with cilia. Members of this group are divided broadly into the corals, usually colonial animals with either hard or soft skeletons, and the sea anemones, which are solitary polyps without skeletons. Corals are well known for their creation of the beautiful reefs scattered around warm, tropical parts of the world's seas. These reefs are composed of corals with hard skeletons. The animals' ability to extract calcium salts from sea water makes the building of the reefs possible, and their stony structures can reach massive proportions. One such example is the Great Barrier Reef along the northwest coast of Australia, which stretches for almost 2,000 kilometres.



Hard corals on the ocean bottom. Above left, a rounded colony (*Goniopora planulata*) with its tubular flower-like polyps. Below right, a hard brain coral (*Lobophyllia robusta*), so named because its convoluted surface resembles that of the human brain.

Hard corals growing just below the low-water mark in the South China Sea show many different growth forms—branching, rounded, platelike or scroll-like.

HARD CORALS

Hard corals *(Madreporaria)* may be single polyps or groups of polyps joined together to form colonies. Calcium carbonate is deposited within the soft tissues of the polyp to form the coral's hard skeleton. Delicate patterns on the skeleton help identify the species.

The chalky skeletons of six species of hard corals. When alive, most were colonies of many polyps. The skeleton at lower left, however, is that of a solitary coral, which consists only of a single polyp.

Hard corals exposed to an ultraviolet lamp, causing them to glow in a ghostly way. This phenomenon is called fluorescence, a bright and glowing condition caused when the corals change the wavelength of the ultraviolet radiation to a longer wavelength that can be seen by the naked human eye.

Tubastrea aurea is a small hard coral that lives in sheltered places under large masses of coral in the Indo-Pacific region. The polyps are brightly coloured in shades of yellow, orange or pink. At right is a starfish.

SOFT CORALS

Soft corals *(Alcyonacea)* form fleshy plantlike growths. There is no compact skeleton but only minute scattered needles of a mineral substance (limestone) to give support to the colony. Often they have a lobed appearance. One kind is called Dead Man's Fingers and another the Sea Cauliflower.

Each soft-coral polyp has eight feathery tentacles.

Making it look like a giant pincushion, polyps project at all angles from the fat, flexible lobes of this soft coral.

HORNY CORALS

The horny corals *(Gorgonacea)* include sea fans and sea whips. The sea whips have long slender stalks but sea fans form branching treelike growths. They have a semi-rigid skeleton of horny substance and are often brightly coloured. They flourish on tropical coral reefs.

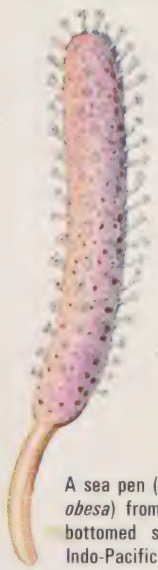
A sea fan that grows in the warm waters of the Caribbean Sea.

The delicate, flexible internal skeleton of an orange sea fan.

SEA PENS

Found in warm seas, sea pens *(Pennatulacea)* look like old-fashioned quill pens made from a feather. Unlike most corals, they have a definite body size. They also have a cylindrical central stem. Extending from both sides of the stem in some forms these are feathery plumes that carry many polyps; the lower portion of the stem is buried in the sand and acts as an anchor.

A beautifully symmetrical sea pen (*Pennatula fimbriata*) which has many small polyps along the borders of its feathery plumes is pictured here.



A sea pen (*Cavernularia obesa*) from the sandy-bottomed seas of the Indo-Pacific.

The stalks of a sea fan covered with tiny white polyps. These stalks may be red, yellow, blue, violet or white.

Space between the rows of feather plumes on a sea pen is the perfect home for a tiny porcelain crab. Each plume carries many polyps.

SEA ANEMONES

The beautiful, flower-like sea anemones *(Actiniaria)* are large, solitary polyps that are attached by their bases to rocks and other objects on the sea bottom. Their movements are limited, though they can move about very slowly by creeping movements. Sea anemones can change their shape considerably: When contracted they look like blobs of jelly, but when fully expanded the centrally placed mouth on the disclike upper surface is clearly visible, encircled by delicate, stinging tentacles. Sea anemones display a variety of colours, often lovely pastel shades.

Paracondylactis hertwigi is an anemone that burrows in the sand in the Northwest Pacific.

A towel anemone (*Stoichactis kenti*) from the Indo-Pacific region. This species can grow quite large and often provides shelter to anemone fish.

This striped sea anemone (*Halisalinella luciae*) is found mostly along rocky coastlines.

The red sea anemone *Actinia equina*, is another that is found near the coast on rocks.

A Japanese sea anemone (*Anthopleura japonica*) that lives on rocky shores in Japan.

The green sea anemone *Anthopleura midori* is found growing in shallow water along rocky coasts.

An aquarium display of Indo-Pacific sea anemones. Two brightly coloured anemone fish can be seen venturing from their refuge among the tentacles of the anemones.

WORMS

Evolution to higher forms of life took a great step forward to produce a large and diverse group of elongated, usually free-living animals with soft, fleshy bodies which can be loosely grouped under the general term worms. Worms are the first animals to show a pattern of body structure that is further refined in higher animals like crustaceans, molluscs and the vertebrates—a distinct head region and a body shape characterised by *bilateral symmetry,* with the body divided along its length into equal left and right halves arranged around a central axis. A clearly defined head with its accompanying sense organs at the front of the body allows the animal to detect both food and danger ahead. It can then take action to either meet or avoid what lies in its path. A body arranged bilaterally is more efficient than the radial arrangement in lower animals like the coelenterates. It provides a more streamlined shape and allows for better locomotion since it can be structured into a series of muscle blocks to operate the limbs or appendages by which the animal moves.

FLATWORMS

Though most of the 15,000 species of flatworms *(Platyhelminthes)* are parasites, living in or on other animals, some are free-living—capable of creeping around by themselves. Flatworms have the beginnings of a centralised nervous system, with a concentration of nervous tissue in the head to form a simple brain that receives impulses from sense organs and transmits messages to the rest of the body. Flatworms also have the beginnings of a head, though the mouth is located in the centre of the underside of the body.

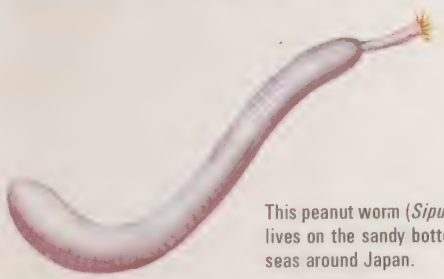
This flatworm (*Planocera reticulata*) lives under stones on Japanese shores.

A planarian flatworm (*Dugesia japonica*), common in fresh water, crawls slowly on the bottom of an aquarium by beating its microscopic cilia. Two primitive eyes can be seen at the front end.

This beautiful flatworm uses its cilia to crawl on the bottom of the Caribbean Sea.

PEANUT WORMS

Peanut worms *(Sipunculida)* are sluggish animals that live on the sea bottom in burrows lined with a slimy substance that they produce called mucus. At the front end of their bodies is a *proboscis,* a tubelike projection carrying the mouth at its tip, which can be turned inside out for feeding. Microscopic food particles are collected by the mucus and moved into the mouth by cilia. The proboscis can be stiffened for burrowing by body fluid under pressure.



This peanut worm (*Sipunculus nudus*) lives on the sandy bottom of shallow seas around Japan.

SPOONWORMS

Spoonworms *(Echiurida)* are sausage-shaped animals that live mostly in burrows in the sea bed. One of the most interesting spoonworms is called the "fat innkeeper" because it shelters many animals in the U-shaped burrow it makes in the mud. Its guests include crabs and gobies as well as other worms. The innkeeper feeds by producing a net of slime that fits over its head. The worm draws water and the minute food it contains into the net by contracting its body. The slime and any food in it are then periodically swallowed.

RIBBON WORMS

The structure of ribbon worms *(Nemertina)* resembles that of the flatworm except that the mouth is at the front end of the body with the head. Some ribbon worms grow to one metre in length, and the proboscis when fully extended is even longer than the body. This trunklike projection can be turned inside out and used to seize food.

The long and brightly coloured ribbon worm (*Lineus fuscoviridis*) makes its home under stones along Japanese coasts.

This fat innkeeper (*Urechis unicinctus*) is found in the sand along Japanese shorelines.

ROUNDWORMS

Roundworms *(Nematoda)* have long, cylindrical bodies, pointed at each end and covered with a strong, horny layer of cuticle on the outside. Some are microscopic, but the largest reach one metre in length. They are found everywhere—on land, in the sea and in fresh waters—and come in two forms: nonparasitic and parasitic species.

Roundworm parasites in the ovaries of a dead fish.

SEGMENTED WORMS

Segmented worms *(Annelida)* make up one of the most important groups in the animal kingdom. They are the first simple animals with bodies built in a segmental pattern, which has evolved into the complicated and jointed bodies of higher animals such as lobsters, shrimps and crabs. Within this group are marine worms, with bodies possessing many bristles; a number of worms with fewer bristles that live either on land or in fresh water—the common earthworm is the best known of this grouping; and leeches without any bristles. Segmented worms have bodies clearly divided up into rings or segments. Except for the head and the last segment, the body segments are all alike both on the outside and internally. Each segment shows an outer tubelike muscular body wall, an inner tubular gut and the same arrangement of nerves and blood vessels. Also, each of the animal's segments contains compartments filled with fluid. By contracting its muscles the worm can compress the fluid and change the shape of each compartment, enabling it to burrow and swim.

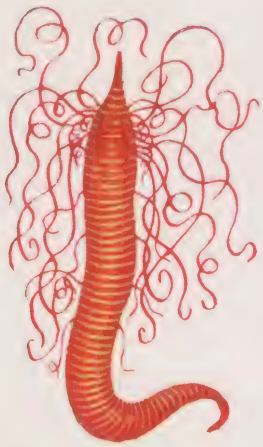
The scale worm (*Harmothoe imbricata*) is found under stones along rocky coasts.

The bottom-dwelling sea mouse (*Chloeia flava*) is named for its dense coating of fine bristles resembling fur, which can be irritating to the touch.

BRISTLEWORMS

Bristleworms *(Polychaetes)* take their name from the numerous hairlike projections found all over their bodies. These grow out of a pair of fleshy lobes found on the sides of each segment that rings the worm. Nearly all bristleworms live in the sea and vary in length from a few millimetres to more than 6 metres long. Some move about freely; others live in cylindrical tubes that they construct on the ocean bottom. Bristleworm colours range from dull to very bright, and some of them even give off light from within their bodies. Like most marine worms, bristleworms go through a larval stage.

The elongated proboscis attached to the head of this burrowing *Glycera* worm is normally folded up inside the head. But it can be turned inside out and rapidly extended to seize small animals with its horny teeth.



The hairy-gilled worm (*Cirriformia tentaculata*), found on sandy shores, gets its name from the long, curling gills that grow like whiskers from the first few segments of its body.

WANDERING BRISTLEWORMS

Wandering bristleworms *(Errantia)* are free-living and can burrow, swim and crawl. They thus have more highly developed sense and locomotory organs than worms that do not move about freely and spend their lives in tubes.

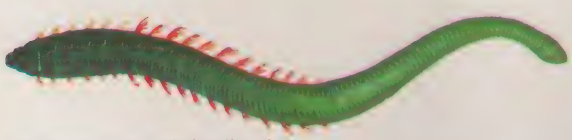
The long-bristled sandworm (*Tylorrhynchus heterochetus*) lives in muddy estuaries. It is used as bait for fishing.

The clamworm (*Neanthes diversicolor*) lives in muddy estuaries. It is used as live bait for fishing.

A palolo worm of a species (*Eunice aphroditois*) found in the Indo-Pacific region.

PALOLO WORMS

Palolo worms live on shallow, rocky sea bottoms. Certain varieties are famous for their unique method of reproduction. Once a year the hind part of the worm, which contains either male or female sex cells, breaks off and swarms to the surface while the front end continues its life on the reef. The timing, giving the sperm and eggs the best possible chance of meeting for fertilisation, can be very precise—in the southern Pacific the swarm occurs at dawn on the day of the last quarter of the October-November moon.



The lugworm *Arenicola brasiliensis*.

LUGWORMS

The lugworm is large and lives in a U-shaped burrow in the sand which it lines with mucus. It turns its mouth cavity inside out to swallow large amounts of sand. Minute quantities of digestible material are absorbed, and the rest passes straight through the gut and out of the body, leaving coiled, wormlike structures called worm casts that are often seen on sandy beaches at low tide. Projecting from both sides of the lugworm's body are feathery red gills.

FANWORMS

Fanworms, or tubeworms *(Sedentaria),* are sedentary bristleworms that protect their soft bodies by living in tubes after the larval stage. The tube is either soft and membranous or made of a cementing substance created from lime salts produced from a special organ behind the worm's head. Only a crown of tentacles can be seen outside the tube. This is a special food-gathering organ which looks like a crest of feathers. When food particles of living or dead matter come in contact with any part of the crown, they are trapped and transferred to the mouth. The slightest disturbance in the water—even a shadow suddenly falling across the fanworm—will cause the animal to withdraw its feeding crown instantly. When the worm spreads it out again, it does so very slowly.

The fanlike feeding crown and the tail of a fanworm (*Sabellastarte indica*) project from opposite ends of its soft, membranous tube. The tail cannot normally be seen.

The burrowing, tube-dwelling terebellid worm (*Loimia medusa*) is found in sandy, shallow waters of the Northwest Pacific. Long, tentacle-like structures project from the animal's first body segment and serve as gills.

This fanworm (*Diopatra sugokai*) lives in the sand in a tube made of various sea-grasses and seashells stuck together.

Featherduster worms (*Spirobranchus giganteus*) of different colours extend their feeding crowns from tubes buried in hard corals. The crowns, which resemble old-fashioned featherdusters and give the animals their name, may be one of several colours, some of which are shown here.

The delicate feeding crown of a sabellid fanworm emerges from the animal's soft, membranous tube.

The beautiful white feeding crown of a serpulid fanworm looks like a delicate undersea flower.

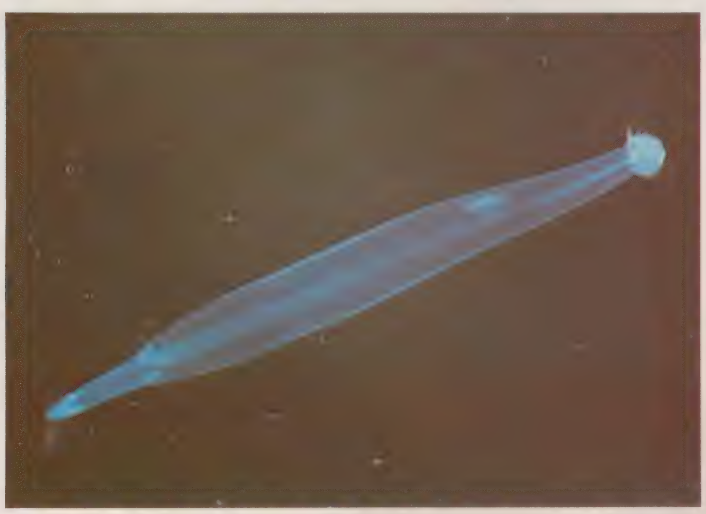
FRESHWATER SEGMENTED WORMS

Freshwater segmented worms are included with the land-dwelling earthworms in the group *Oligochaeta*. They have reduced heads and few bristles. Each worm has both male and female reproductive organs, and the young grow up without going through a larval stage. One freshwater segmented worm is the bright red tubifex, or bloodworm, a small animal that lives head down in the sandy or muddy bottoms of ponds, creeks and rivers, often in sufficient numbers to colour the mud red. Its tail end sticks out of the mud and waves vigourously, probably to stir up a steady flow of water from which it absorbs oxygen. The animal can survive in heavily polluted water that is low in oxygen. Tubifex worms are a good food for aquarium fish.

Their heads buried in the sandy bottom, Tubifex worms wave their tails in the water.

ARROW WORMS

Arrow worms *(Chaetognatha),* named after the shapes of their bodies, are tiny, transparent, planktonic animals, usually about one to two centimetres long. More than 1,000 have been found in a cubic metre of sea water. Arrow worms have heads with eyes, jaws armed with bristles, and tails but possess no respiratory or excretory organs. Although they do not swim very well, they are balanced in the water by finlike projections. Their main source of food is other animal plankton, which they catch with the long bristles on either side of the mouth. The name "chaetognath" in fact means "bristle-jawed."



Arrow worm *Sagitta inflata*. The food-gathering bristles on each side of the mouth can be seen.

LEECHES

Leeches *(Hirudinea)* are bloodsucking worms with no bristles. They have suckers at both ends of their bodies that are used for locomotion and for attaching to their victims. They are also able to swim, using wavelike movements that pass from the front to the back of their flat bodies. Leeches can draw blood, using little teeth found in the front sucker, and they produce a salivary substance called hirudin that prevents clotting. They can drink many times their weight in blood. Medicinal leeches were once used in Europe to draw blood from sick people in the belief that the practise could cure disease. "Leechcraft," in fact, is an old-fashioned word for the practise of medicine, and the doctor was often called "the leech."

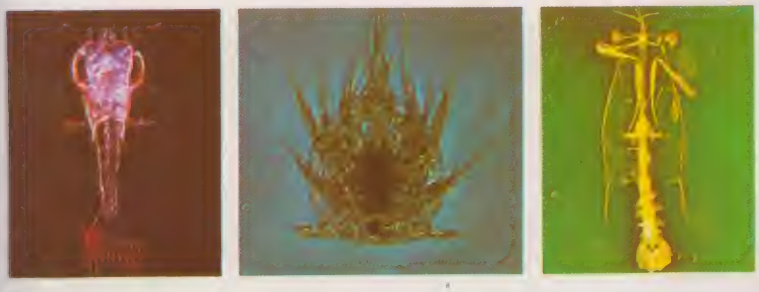
The freshwater medicinal leech (*Hirudo medicinalis*) sucks the blood of animals in the water.

The aquatic leech *Pontobdella bimaculata* attaches itself to sharks and other marine animals. It uses the large sucker at the rear of its body to cling to its host while it sucks the victim's blood with the smaller sucker on its other end.

CRUSTACEANS

Crustaceans form a large class of invertebrates that includes the familiar lobsters, crabs and prawns as well as barnacles, water fleas, sea slaters and planktonic animals that drift in the sea. Like spiders and insects, crustaceans belong to a vast group of animals called *arthropods*, which have jointed limbs (arthropod means "jointed leg"), segmented bodies and external skeletons, or shells, that are shed as they grow. Although there are land species, most crustaceans live in water and breathe through gills. Their young pass through one or more larval stages.

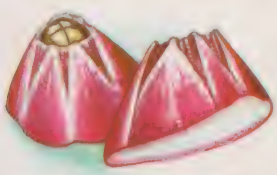
The photographs above show (from left to right) the first, second and third stages in the development of a crab larva.



These photographs (from left to right) show the larval stage of a lobster, an acorn barnacle and a mantis prawn.

BARNACLES

Barnacles *(Cirripedia)* are small crustaceans that spend their adult lives attached to rocks, wooden pilings, the hulls of ships, the bodies of other animals or plants or any floating object, even glass and lumps of solidified crude oil. Because they have evolved towards a fixed mode of life, they do not need many of the organs required for a free-living existence, thus their organs are small or have disappeared. They have no eyes, antennae or walking legs. Since barnacles have no means of escape they are protected by hard, thick shells. For feeding they use their feathery legs to rake the water for minute food particles with a series of rhythmic movements. Their larvae are free-swimming and are an important source of food for larger animals.



These acorn barnacles (*Balanus tintinnabulum*) are found in the cold waters of the North Pacific.

These acorn barnacles (*Balanus amphitrite hawaiiensis*) dwell in the Pacific Ocean.

The large stalked barnacle (*Scalpellum stearnsi*) lives attached to rocks at depths of 160 metres in the Pacific Ocean.

CRUSTACEAN PLANKTON

Some tiny crustaceans spend their whole lives drifting in the sea, combining with other tiny animals and plants to form plankton. They eat one-celled animals and plants and in turn are eaten by small fish, thus constituting one of the major sources of food in the oceans. Most crustacean plankton have long antennae and bristles which help to increase their surface area and prevent them from falling quickly through the water. The larvae of various other crustaceans are also planktonic creatures before they develop into mature animals like barnacles, prawns, lobsters and crabs.

A small, deep-sea planktonic crustacean called Phronima feeds on a transparent barrel-shaped salp, a relative of the sea squirt. After eating the living tissue, the Phronima takes shelter and lays its eggs inside the salp's tough outer skin.

Seen here greatly enlarged, the planktonic calanus (*Acartia clausi*) and its relatives are filter feeders and have simple hearts.

A young barnacle growing on its shell, a large goose barnacle (*Lepas anatifera*) has attached itself to a floating plastic bottle.

DECAPODS

Prawns (often called shrimps), lobsters and crabs form a group called *Decapoda* which accounts for nearly one third of all crustaceans. In decapods the head and central part of the body or thorax is covered by a hard shell called a *carapace*. This protects internal organs including the intestines. Gills are used for breathing. In prawns and lobsters the abdomen is long and divided into distinct segments. In crabs the abdomen is a small flat structure pressed against the underside of the body. Decapods have five pairs of legs. The two front ones have pincers that are used to seize food and for defence.

Since the crustacean's shell cannot expand, the animal grows by *moulting*—discarding its old shell and producing a new, larger one. In crabs and lobsters the shell is hard and limy, while in prawns and many smaller species it is horny and flexible. Lobsters and prawns escape in an emergency by darting backwards. By bending their abdomens suddenly, they can quickly flick their fanlike tail. Prized as food, many decapods are commercially important.

The mud lobster (*Thalassina anomala*) lives in semi-liquid mud near the highwater tidemark in the tropics. It feeds on small animals living in the mud. It is rarely seen at the surface, but it leaves its burrow at night and after rain.

The succulent, delicious meat of the Maine lobster's large claws make him a favourite on the American dinner table.

As the mud lobster burrows it often leaves behind deposits of mud up to one metre high, which look rather like volcanoes. This activity may cause whole embankments to collapse. In Southeast Asia it also may create conditions for malarial mosquitoes to breed in brackish water.

The baby (bottom) and adult Japanese spiny lobster (*Palinurus japonicus*). Found in Pacific waters at depths up to 50 metres, the spiny lobster is delicious to eat.

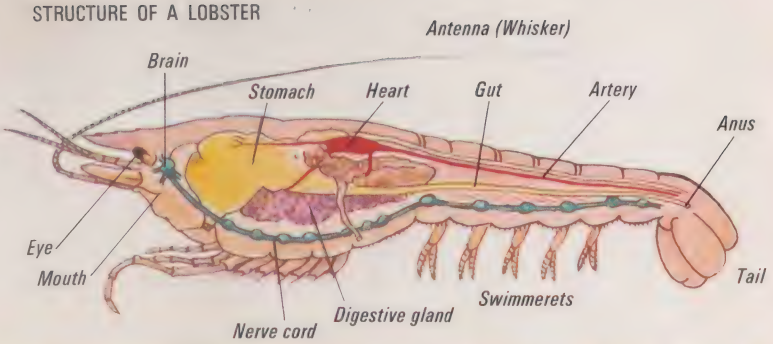
This squat lobster (*Ibacus ciliatus*) lives on sandy and muddy sea bottoms in the western Pacific Ocean.

The coral spiny lobster (*Palinurus versicolor*), found on the rocky shores of warm Pacific seas.

STRUCTURE OF A DECAPOD

The lobster's outer skeleton or shell is formed of plates of hard, limy material and held together by joints of tough and flexible skin. The long abdomen is divided into segments, each having a skeletal plate and a pair of limbs called *swimmerets,* which fan water over the gills. A nerve cord runs the length of the body, with a specialised enlargement, the brain, at the head end. The illustration at right depicts the various organs in a lobster's body.

STRUCTURE OF A LOBSTER



The prawn (*Metapenaeus joyneri*), which inhabits the Inland Sea of Japan.

The North Pacific prawn (*Pandalus borealis*).

This brightly coloured mantis prawn inhabits the coral reefs around Sri Lanka.

The pistol prawn, or snapping shrimp (*Alpheus brevicristatus*), is common in shallow tropical waters, where it lives in a burrow, often in the company of blennies. It can make a loud, snapping noise by suddenly closing its big claw—with enough force to stun its prey.

MANTIS PRAWNS

The predatory mantis prawn *(Squillidae)* is found in warm, coastal waters. Its name comes from the fact that its long claws resemble the grasping arms of the insect called the praying mantis. The claws, the second pair of legs on the animal's elongated body, fold up like a penknife by means of a spiny segment that fits into a groove. The prawn darts out of its burrow to seize its prey with these deadly pincers. The gills of the mantis prawn are carried on the swimmerets of the abdomen.

The internal structures of these transparent Pacific prawns (*Parapendalus spinipes*) can be seen through their horny shells.

This *Squilla raphidea* is a mantis prawn that thrives on muddy sea bottoms in southern Japan.

The mantis prawn *Squilla oratoria* is widely distributed throughout the Indo-Pacific region.

FIDDLER CRABS

Fiddler crabs, or signalling crabs *(Uca),* live on muddy tropical coasts between high- and low-tide marks. They have keen eyesight, and their eyes are mounted on the end of stalks, enabling them to look over flat sands and shallow water. When danger threatens, they lay their eyestalks flat in grooves on the front of the shell and quickly retreat into their burrows. Males defend the territory around their burrows and often fight. Males have two claws, one of which is much larger than the other. The larger one is brightly coloured and is used only to threaten other males and attract females. The other claw is very small and used for feeding. Should the male lose its large claw in a fight or for some other reason, the small claw will develop into a large one and a new small claw will grow in the place of the large one that was lost.

Fiddler crabs eat organic material from the surface film of mud, which is put in the mouth and washed to separate the edible matter. Just before the rising tide covers them, each enters its own burrow and blocks the entrance with a plug of mud. In this way they are able to breathe air when the water covers the burrow. Fiddler crabs mysteriously change colour from night to day. Yellowish-white at night, they begin to darken around sunrise, reaching maximum pigmentation when they emerge from their burrows at low tide.

Its large claw prominently displayed in front of it, a male fiddler crab (*Uca vocans*) emerges from its burrow.

A male fiddler crab (centre) with two females. Unlike males, female fiddler crabs have no big claw, and both claws are being used for feeding.

SWIMMING CRABS

Unlike many crabs that crawl along the sea bottom or shoreline, swimming crabs *(Portunidae)* are strong, fast swimmers capable of migrating long distances in the water. This is possible because the fifth pair of legs has been modified into paddles. Swimming crabs often burrow into the sand during the day, leaving only their eyes exposed. Certain species have shells with sharp projecting spines, making it impossible to pick them up in the same way as other crabs. Other crabs can be held between the forefinger and thumb by gripping the sides of the body just in front of the last pair of legs.

The sharp spines on the shell of *Portunus trituberculatus* make it impossible to pick up.

Japanese swimming crab *Charybdis japonica.*

The swimming crab *Ovalipes punctatus.*

A swimming crab (*Portunus trituberculatus*) on the sea bottom. Its paddle-like swimming legs can be clearly seen at the rear of its body.

SPIDER CRABS

Spider crabs *(Maiadae)* are generally slow-moving, sluggish animals with thick, rounded bodies and long, slender legs. Their body surface is usually covered with hairs, spines and other projections, as well as with small plants and animals like algae, sponges and sea anemones. Some crabs attach these substances to themselves with a mucus-like secretion from their mouths. Such an appearance conceals the crab's outline and thus provides it with effective camouflage and protection.

The large, grinding mouthpart of the giant spider crab consists of five pairs of modified legs, which, by their combined action, are able to cut up food into small pieces.

This spider crab (*Chionoecetes opilio*) lives in water about 100 metres deep.

The giant spider crab (*Macrocheira kaempferi*) of the North Pacific is the largest crab in the world, almost four metres wide with legs fully extended.

The poisonous tentacles of the hydroid polyps this spider crab (*Hyastenus diacanthus*) carries on its body protect the crab from its enemies. The hydroids gain the ability to move around by riding on the crab.

This spider crab (*Camposcia retusa*) has effectively concealed its outline by covering itself with plants and other animals.

GHOST CRABS

Ghost crabs *(Ocypoda)* are found on most sandy tropical shores. They make burrows about one metre long just above the high-tide mark and shelter in them during the heat of the day. They run very fast, and their sandy colour makes them difficult to see. With eyes on stalks they are able to hunt prey on the beach. They can also catch flies from the bottoms of leaves with their claws. They also prey on newly hatched baby turtles.

The common rock crab (*Plagusia dentipes*).

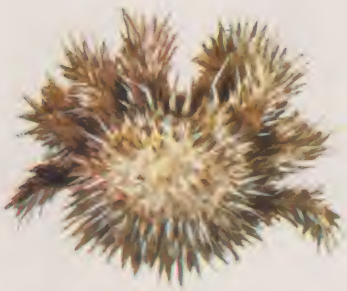
The ghost crab *Ocypoda stimpsoni* on the sands.

The three-toothed frog crab (*Lyreidus tridentatus*).

The red frog crab (*Ranina ranina*).

The Heike crab (*Dorippe japonica*) lives on sandy sea bottoms at a depth of about 50 metres. The Japanese see the pattern on the crab's shell as a weeping human face that calls to mind the tragic defeat of a famous samurai clan named Heike in 1185. In Southeast Asia one species of *Dorippe* regularly floats far out to sea clasping the stiff leaf of a mangrove tree.

The porcelain crab (*Neopetrolisthes ohshimai*) lives on rocky shores in Japan.



The Japanese chestnut crab lives at a depth of 200 metres. Its name comes from the fact that it resembles a chestnut in its spiny seedbox.

A square-bodied box, or mangrove, crab (*Sesarma*) climbs out of the water. Commonly found in the mangrove swamps of Southeast Asia, the male box crab is said to make a creaking noise with its filelike claws to attract the female.

The tropical pebble crab (*Leucosia obtusifrons*).

The furry crab.

The Myrafugax crab has a small body and extremely long claws.

A fight over territory between two male soldier crabs (*Dotilla mictyroides*). Vast numbers of these small animals live on the sand flats of Southeast Asia. They use their big claws to shovel sand into their mouths, where it is sluiced with water to extract edible material. When the tide rises, soldier crabs trap air by building an igloo-like dome of sand. They then bury the trapped air bubble by scooping up the floor of the igloo and putting it on the ceiling. This air is used for breathing while the tide is high. The male at the right, in the process of building his igloo, was angered when another male ventured too close, and a fight ensued.

HERMIT CRABS

Hermit crabs *(Anomura)* are specially adapted to live inside the shells of dead marine snails. The front part of the body has a hard shell and legs, but the tail is soft and coiled centrally and usually to the right to fit the spiral cavity of the snail. The abdomen has lost almost all its appendages, such as the swimmerets and tail, but does retain a hooklike pair of legs at the rear which helps the animal to fix itself inside the shell.

Hermit crabs withdraw into their shells when danger approaches; without the protection of their borrowed homes they are quite defenceless. As they grow, however, they must periodically leave their shells to find larger ones into which to move. Hermit crabs are found all over the world in the sea and occasionally on land and in trees. Hermit crabs have been known to move into such various makeshift homes, in addition to seashells, as bamboo stems, broken coconut shells, corals, sponges and even hollow cylinders of wood. This peculiar lifestyle can be rather entertaining to observe.

A hermit crab (*Dardanus arrosor*) with a sea anemone attached to its shell. The anemone helps to camouflage the crab, and its stinging tentacles discourage any predators not fooled by the disguise.

A hermit crab (*Pagurus samuelis*) that inhabits the rocky shores of the North Pacific, shown without the shell in which it lives. The animal's asymmetrical body is adapted to coiling up in a snail shell.

The land hermit crab spends a good deal of time above the tideline and may sometimes carry his shell as far as 100 metres inland from the shore.

A hermit crab inhabits a cone shell on the coral reefs of Sri Lanka.

ROBBER CRABS

Robber crabs *(Birgus latro)* are the largest of all hermit crabs, reaching a length of about 30 centimetres and weighing about 3 kilograms. Their giant claws can easily sever a finger. Living on a few coral islands of the Indo-Pacific, these animals return to the sea only to breed. Robber crabs are scavengers, feeding on fruit and carrion, and often climb trees to reach a meal. They get their name from their habit of dragging off almost anything—including knives and forks left behind by picnickers. Unlike other hermit crabs, they do not live inside the shells of other animals.

The robber crab (*Birgus latro*).

SEA SLATERS

Sea slaters like *Ligia exotica* (right) are marine crustaceans that live on rocks just above the high-tide mark but scavenge on seaweeds during low tide. They have seven pairs of legs and slightly arched bodies covered with wide armour-like plates. A similar-looking animal, known as the common wood louse, belongs to the same order as the sea slater but lives on land.

HORSESHOE CRABS

Despite their name, horseshoe crabs, or king crabs *(Xiphosura)* are not crustaceans and in fact are more closely related to scorpions and spiders than they are to crabs. Links to the distant past, they have remained unchanged for hundreds of millions of years and thus are often called living fossils.

The body of the horseshoe crab is divided into three connected parts: the large, horseshoe-shaped shell that covers the fused head and thorax and gives the animal its name; the shell-like abdomen that carries the gills on the underside; and the spinelike tail or telson. Two pairs of eyes are located on the arched upper surface of the shell, one pair of tiny eyes near the middle and one pair of large eyes at the sides. Horseshoe crabs usually move along the sea bottom by arching their bodies and then pushing with the last pair of legs and the tail, but they are also capable of swimming—by flipping over on their backs and beating the gill flaps. After swimming upside down, they use their tails to right themselves again.

This horseshoe crab (*Tachypleus tridentatus*) lives on the muddy bottom of the Inland Sea of Japan.

Two horseshoe crabs (*Carcinoscorpius*) swimming upside down. The animals are often seen in pairs when they come into shallow water to bury their eggs in the sand.

SEA SPIDERS

Sea spiders *(Pycnogonida)* are marine arthropods. Most have bodies divided into four segments and four pairs of long, slender legs on which they crawl along the sea bottom or among plants and animals. Certain species are capable of treading water. They have a mouth at the end of a sucking proboscis that can be longer and larger than the animal's body itself. This proboscis is used to suck the juices from the soft-bodied invertebrates on which sea spiders often feed.

The small sea spider *Lecythorhynchus hilgendorfi* (right) lives among the bases of seaweeds along the rocky shores of the North Pacific.

FRESHWATER CRUSTACEANS

Crustaceans are found in fresh water as well as the sea. They are mostly small animals that compete with insects in lakes, ponds and ditch water for the minute organisms on which they feed, and serve in turn as a source of food for larger animals like fish. Some freshwater crustaceans, like water fleas, have interesting methods of reproduction. The water-flea population is made up largely of females that give birth to young by a special process called *parthenogenesis* in which the eggs can develop without fertilisation by a male. These unfertilised eggs grow into females. But when conditions in the ponds, streams and ditches where they live become difficult, as when winter approaches, some of the eggs will develop into males.

This crab (*Potamon dehaani*) lives in Japanese rivers.

A burrowing river crayfish (*Cambaroides japonicus*) from North Japan.

This pond prawn (*Palaemon paucidens*) lives in both still and moving fresh water in Japan.

Under a microscope you can observe the eggs, eye and antennae hairs—used for swimming—of this minute water flea (*Daphnia pulex*).

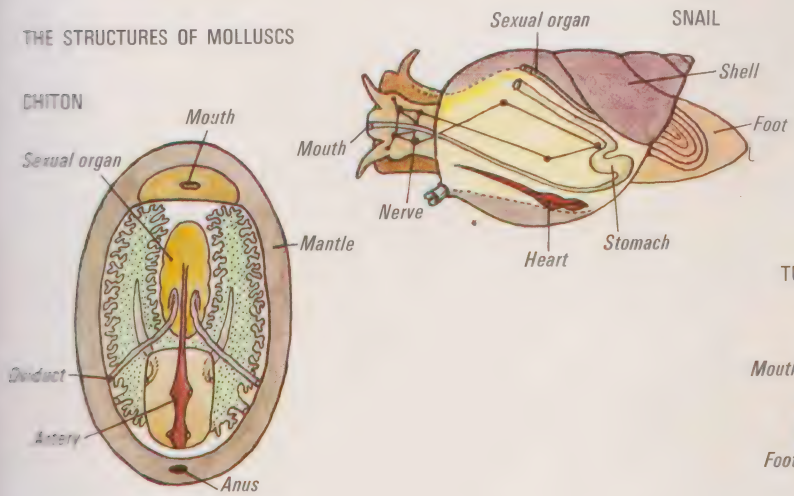
Cyclops—seen here greatly enlarged—is a tiny crustacean found in still bodies of fresh water. It is too small to need a heart and feeds on one-celled plants and animals.

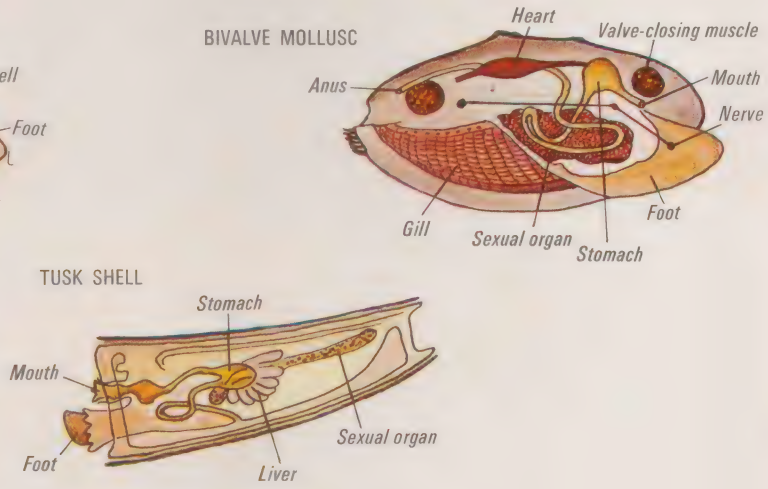
The European freshwater crayfish (*Astacus fluviatilis*) lives in "hard-water" rivers, those that are rich in calcium salts.

MOLLUSCS

With more than 100,000 species, molluscs form one of the largest and most important divisions in the animal kingdom and include familiar invertebrates like snails, clams and octopuses. Though most live in the sea, molluscs are also found in fresh water and on land, from tropical mountain tops to sandy deserts. Most species live in shells which protect their heads and soft bodies. The shell is produced by a membrane covering the body called the *mantle*.

Most species also have a muscular foot that helps them to move about. Octopuses and squid have no external shell but can walk on their tentacles or swim quickly by a kind of jet propulsion. Molluscs have been important to us since primitive days as food and material for making tools and later as money, ornaments and religious symbols. But they can also harm us by carrying diseases, damaging ships and clogging water systems. Some are poisonous.





CHITONS

Very primitive molluscs, chitons *(Amphineura)* are small, sluggish animals with flat oval bodies. They feed on seaweeds. When they have shells, they are made up of eight overlapping plates that cover the flat upper side of the body. Chitons are popularly called "coat-of-mail" shells because their overlapping plates resemble the suits of armour worn by mediaeval knights.

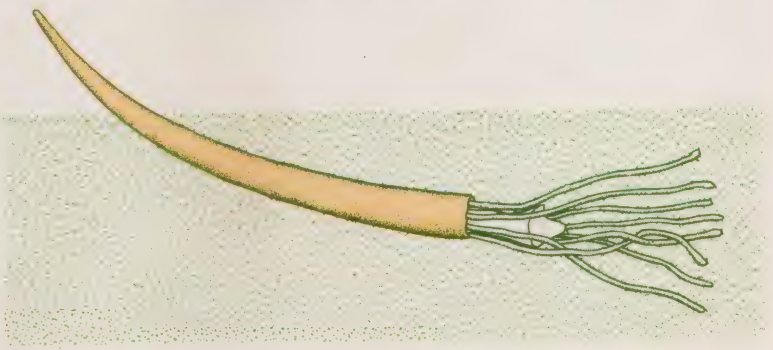
A chiton (*Ishnochiton comptus*) found on rocky Pacific shores. The eight plates making up the shell can be clearly seen.

This is the brightly coloured Pacific chiton, *Onithochiton hirasei*.

A chiton on a rocky shore in New Zealand feeds on minute algae attached to the rocks.

TUSK SHELLS

Tusk shells *(Scaphopoda)* have slender tubular shells that are slightly curved and open at both ends. The animal inside is very simple. Though it does have a mouth, jaws, tentacles and a digestive system, it has no true head, eyes or gills. The sexes are separate, and the young pass through a planktonic larval stage. The adults protect themselves by burrowing into the sand.



As the tusk shell moves slowly through the sand it catches small particles of food on its knobbed and sticky tentacles and transfers them to its mouth.

A tusk shell (*Dentalium octangulatum*) which lives on the sandy bottom of the Inland Sea of Japan.

This tusk shell (*Fissidentalium formosum*) inhabits shallow waters around Taiwan and farther north.

This long, curved tusk shell (*Fissidentalium vernedei*) is found in waters south of Japan at a depth of 20 metres.

UNIVALVE MOLLUSCS

Univalves *(Gastropoda)*, the largest group of molluscs, include marine animals like cowries, cones, limpets, whelks and sea slugs as well as freshwater species like pond snails. Most have spiral shells, but some have shells of a different shape or no shell at all. The word snail is commonly applied to those with a coiled spiral shell. The shell grows from the edge of its open end, and the number of spirals indicates its age. Univalves have tentacles, eyes and a mouth containing the *radula*, a rasping organ set with many horny teeth. Most feed on vegetable matter, though some, like cone shells, whelks and certain snails, eat other animals.

Most univalves use their wide, flat foot to creep along the ground, but some float in water, and a few have a fin-shaped foot for swimming. An individual univalve may have both male and female reproductive organs in its body. The young usually pass through a planktonic larval stage before developing their heavy shells and sinking to the bottom. Though freshwater snails do not have larvae of their own, they often play host to the larvae of parasitic worms that transmit serious diseases to humans. The shells of certain univalves like the cowrie have been greatly prized in some societies where they were used as ornaments, money and religious symbols.

A nerite snail (*Theliostyla albicilla*).

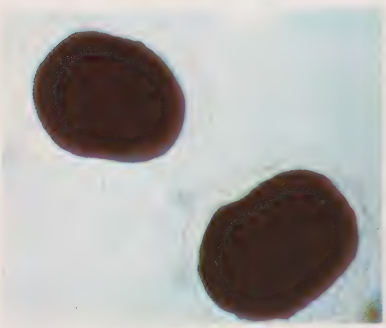
The tapestry turban (*Turbo petholatus*).

Slitshells like *Mikadotrochus teramachii* are living fossils since they existed on earth millions of years ago. Only 13 species survive.

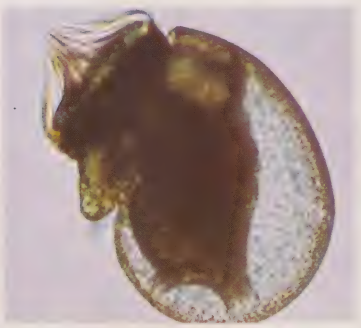
This olive snail (*Oliva mustelina*) is found in the tropics of the Indo-Pacific.

The triumphant star (*Guildfordia triumphans*) is found at depths greater than 50 metres.

LIFE CYCLE OF THE ABALONE



This mollusc's cycle begins with abalone eggs floating in the water.

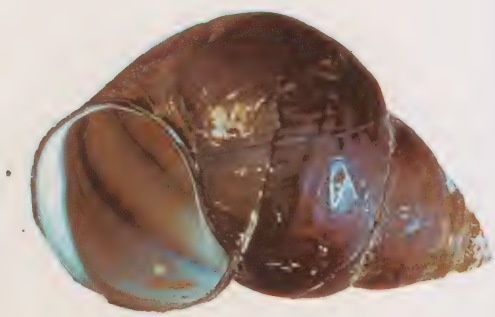


In the next stage the abalone's larva begins to develop a shell.

The shell is now formed. At this stage the abalone will attach itself to a rock.

The young adult. Water passes through the holes in the shell.

A common European pond snail (*Limnea stagnalis*) crawls along the bottom.



A giant Japanese pond snail (*Cipanopaludina japonica*).

A Japanese marsh snail (*Stenomelapia costellaris*).

The beautiful lavender mantle of this egg cowrie (*Primovula rhodia*) is covered with yellow spots and projections.

The spindle egg cowrie (*Phenacovolva*) creeps along part of a sea fan. The markings on its brown, speckled mantle resemble those of the sea fan, making it difficult to recognise as a mollusc.

Having rolled a snail over on its back with its long proboscis, the cloth-of-gold cone shell (*Conus textile*) poises for the kill. In a split second it will shoot a poison harpoon through the proboscis into the victim. Though different species feed on different animals, all cones are carnivorous. Certain fish-eating species are so deadly that they are capable of killing a human.

The beautiful, delicate paper bubble shell (*Hydatina physis*) is related to sea slugs and found in most tropical seas, where it uses a special head shield to plough in the mud. The animal has only one lung.

Its mouth open and radula teeth extended, a nerite from Southeast Asia scrapes algae off a glass.

The tiger cowrie (*Cypraea tigris*) from the Indo-Pacific. The mantle with its many fleshy projections is partly extended over the shell it has produced. Two tentacles can be seen on the left.

A tun shell (*Tonna*) from West Africa. One eye can be seen at the base of a tentacle. The respiratory siphon, a tube for taking water into the gills, projects upwards.

This rare murex (*Chicores saulii*) lives in tropical areas of the Pacific.

The whelk *Neptunea polycosta* lives in cold waters and feeds on other molluscs. All whelks are carnivorous.

A tun shell (*Tonna sulcosa*), which lives 80 metres deep.

The Venus comb murex (*Murex pecten*) is found at depths of 20 metres.

The snipe's bill murex (*Haustellum haustellum*). One species of murex from the eastern Mediterranean was used to make the purple dye for the robes worn by Roman Emperors.

A limpet (*Cellana grata*) from the rocks of the West Pacific.

The Oregon triton (*Fusitriton oregonensis*) is delicious to eat. The larger species of triton are often used as native trumpets after the tip of the spire has been cut off.

The precious wentletrap (*Epitonium scalare*) is a rare shell found at depths of 200 metres. The precious wentletrap is carnivorous.

The knobbed whelk (*Hemifusus ternatanus*) of the West Pacific.

SEA SLUGS

Sea slugs, or sea hares *(Opisthobranchia)*, are marine gastropods that do not have shells. Some can swim, but most creep along the sea bottom in shallow waters. Most feed on seaweeds, but some eat sponges or even coelenterates such as sea anemones and corals, including those that have stinging cells which are swallowed whole without discharging the poison. The cells pass from the slug's gut into hollow, brightly coloured projections on its back. These projections serve as brilliant reminders to any would-be predator that to attempt to eat the slug,will mean risking getting stung by the slug's last meal. Sea slugs also protect themselves by emitting a cloud of dark fluid to confound predators.

The sea slug *Melibe vexillifera* lives in shallow water.

The sea slug *Ceratosoma cornigerum*.

Two vivid sea slugs (*Clossodoris gloriosa*) which are normally seen in summer in the North Pacific.

This bright blue sea slug (*Aeolidiella*) makes its habitat in shallow waters of the Northwest Pacific Ocean.

This Japanese sea slug (*Aeolidiella takanosimensis*) is found along rocky coastlines.

Glaucus atlanticus is a rare planktonic sea slug that floats on the surface in warm tropical seas. It feeds on floating coelenterates like the Portuguese man-of-war and by-the-wind sailor.

A brilliantly coloured sea slug (*Cyerce nigra*) that is found in the Indian Ocean.

This sea slug (*Glossodoris festiva*) inhabits shallow waters where there are plenty of seaweeds.

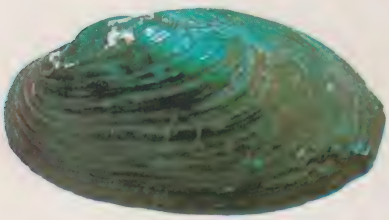
This sea slug (*Platydoris speciosa*) is another commonly found on rocky shores.

This large sea hare (*Aplysia kurodai*) emits a purple, inky substance to protect it from attack.

BIVALVE MOLLUSCS

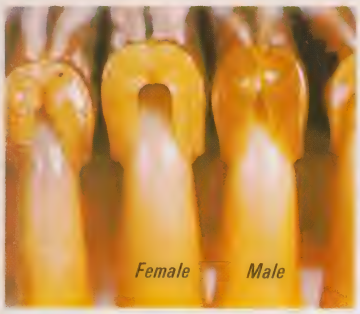
Bivalves *(Pelecypoda)* are the second largest group of molluscs, and certain members, like oysters, clams and scallops are considered important food sources for us. About two thirds of them live in the sea. Each bivalve is covered by two shells, called valves, which are hinged together with a band of tough, fibrous material. As the shell grows, successive ridges are formed; the number of ridges shows the animal's age. When the animal is resting its shell may be opened slightly, but it can be quickly snapped shut by a powerful muscle. Gills are found in the mantle cavity between the foot and the mantle. Water flows through the cavity via two tubular siphons. One directs water in for removal of oxygen and food particles, and the other passes it out. Most species use their foot to dig into the soft bottom and bury themselves, but some, like mussels and oysters, attach themselves to solid objects such as rocks and piers. Mussels anchor themselves by strong threads and oysters by secreting a cementing substance.

A freshwater clam (*Corbicula leana*) with its foot extended for digging in the sand.



A Japanese freshwater mussel (*Obovalis omiensis*). Freshwater mussels are found in most of the world's rivers and ponds, and some species produce crude pearls.

This razor shell has its foot extended into the sand.



Extended feet of male and female razor shells seen from rear.

Egg of a razor shell appears marked by tiny lines.

A mantle scallop (*Gloripallium pallium*).

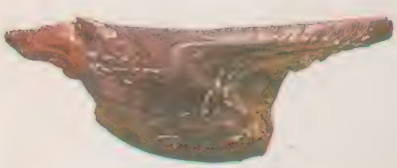
Mantle just starting to form a shell.

Young razor shells.

Adult razor shells.

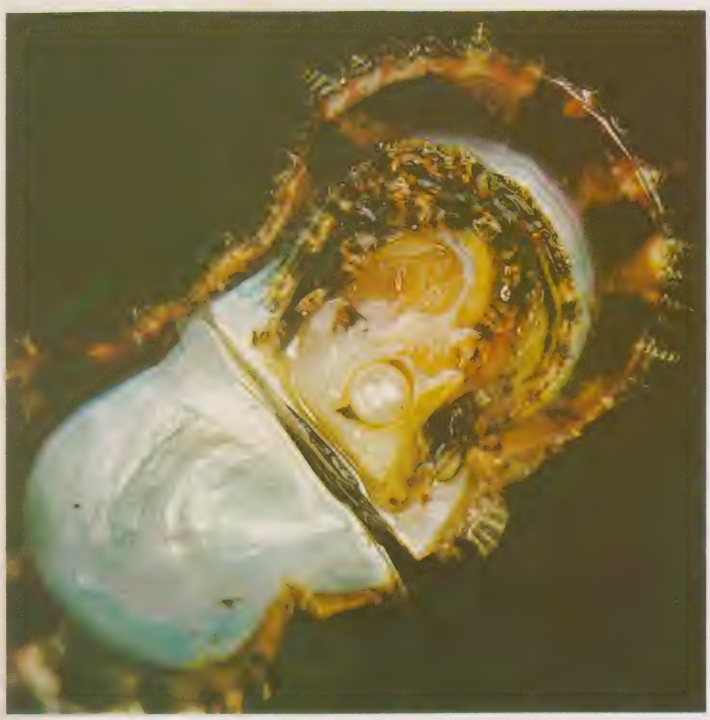
HOW A PEARL IS FORMED

The inner surface of pearl oysters and many other marine molluscs is a beautiful hard, smooth, crystalline substance called *mother-of-pearl,* or *nacre.* This is produced by the mantle. If a small object becomes lodged between the mantle and one of the valves of a pearl oyster, the mantle may cover it with coats of nacre to finally produce the familiar pearl. Thus the beautiful pearl, so highly prized as a gem, is for the oyster merely a way of dealing with an irritating piece of grit. Such natural pearls are produced in only a small proportion of oysters, but cultured pearls can be produced by introducing artificial irritants into oysters raised in undersea farms.



The winged pearl oyster (*Pteria austropteria brevialata*).

The Japanese pearl oyster (*Pinctada fucata*) is cultivated for cultured pearls. Calcium carbonate spheres are put into the mantle, and the oyster produces a coating of real pearl substance around it.



The shell of a pearl oyster is opened to reveal a glistening pearl nestling in the animal's soft flesh.

The hammer oyster (*Malleus albus*) takes its name from its shape. It lives on the sea bottom in waters about 20 metres deep.

A thorny oyster (*Spondylus barbatus*).

A giant clam (*Tridacna gigas*) covered with algae on a coral reef. Giant clams are the largest of all living shells—those living on Australia's Great Barrier Reef can reach a length of more than one metre.

The saucer scallop (*Amusium japonicum*) is found in the waters of the Northwest Pacific.

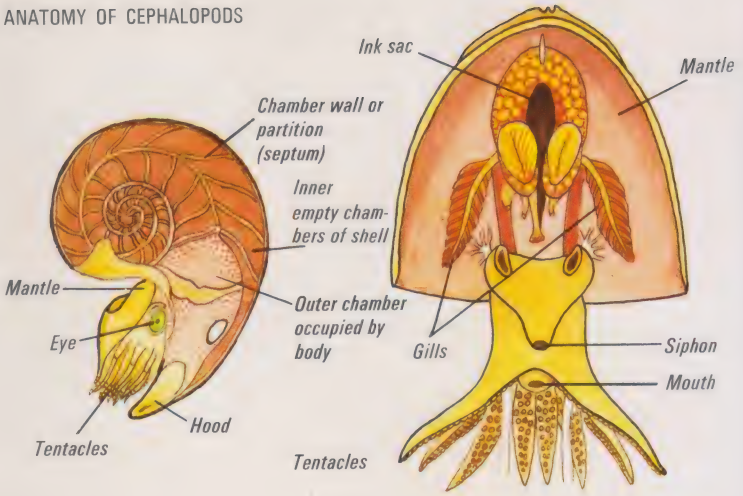
The rotting trunk of a mangrove tree riddled with the chalky linings of the burrows of shipworms (*Teredo*), small bivalve molluscs that burrow into wood. The linings are produced by the mollusc's foot. The shipworm caused terrible damage to wooden ships.

This file clam (*Lima zushiensis*) has long tentacles. It swims by suddenly closing its shell valves.

NAUTILUSES, OCTOPUSES AND SQUID

Nautiluses, octopuses and squid *(Cephalopoda)* are large, active animals whose soft, fleshy bodies carry a big head surrounded by long tentacles bearing suckers. With the exception of the nautiluses, cephalopods do not live in shells like most other molluscs. They have horny jaws and a tubular siphon that they use for both breathing and jet propulsion. They also have very good eyesight. Cephalopods can change colour very quickly to match their emotions. This is done through special muscle cells which cause the red, orange, yellow, blue, violet or black granules in large skin-pigment cells to spread rapidly, becoming more visible. In this way waves of colour can be made to spread over the skin. Some cephalopods have highly developed light-producing organs which when stimulated produce a bright glow by a complex chemical process. Octopuses and squid are important food sources in certain areas of the world.

ANATOMY OF CEPHALOPODS



NAUTILUS SQUID

OCTOPUSES

Octopuses live in holes, caves and even empty jars and cans on the bottom of the sea, emerging to feed on small fish and crustaceans, which they kill by ejecting a poison through their beaks. They usually move slowly, pulling themselves along by the suckers on their eight tentacles. If threatened, octopuses can discharge from a special sac a cloud of ink that acts like a smoke-screen, giving them time to escape their enemies by a form of locomotion resembling jet propulsion: The entrance to the mantle cavity is shut off and the muscle of the mantle contracted, causing a jet of water to shoot from the open siphon and propel the animal rapidly backwards. The siphon also draws water over the gills, thus giving the octopus its oxygen supply.

An octopus emerges from its shelter in search of food.

The giant octopus (*Paroctopus defleini*) lives in the North Pacific, reaching three metres in diameter. It will not attack swimmers and divers, but its poisonous beak should be avoided.

An octopus moves along the ocean floor.

The common octopus (*Octopus vulgaris*) is found in seas all over the world. It grows up to 75 centimetres long.

SQUID AND CUTTLEFISH

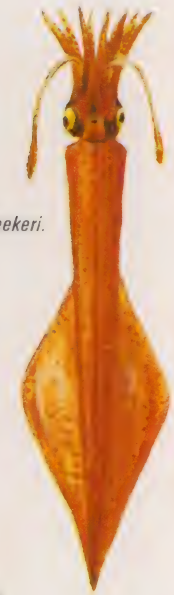
Squid are good swimmers, propelling their streamlined bodies backward or forward by shooting jets of water through their siphons. Small lateral fins are used for moving more slowly through the water while also serving to keep the animals stable. Cuttlefish adjust the amount of gas and water in an internal skeleton made of porous cuttlebone so that they are able to move freely to higher or lower levels in the sea.

Squid have 10 tentacles, all with suction cups; eight are short, but two are long and slender and are used for seizing prey. Squid eyes are almost as complex as those of humans. When laying eggs the female grabs the string of eggs as they leave the siphon, attaching them to the sea bottom or to floating weeds. Large and covered by a white flexible membrane, the eggs hatch into free-swimming larvae. The largest of all invertebrates is the giant squid, a favourite food of sperm whales and probably the source of many sea-monster stories. A giant squid that measured 20 metres when its tentacles were fully extended was once washed ashore in New Zealand.

Cuttlefish closely resemble squid but possess a much thicker internal skeleton made of a porous chalky material called cuttlebone. Cuttlebone is often placed in household bird cages, giving the bird a dietary source of calcium and a place to clean and sharpen its beak.

A male and female cuttlefish with hundreds of eggs in the background. The sexes are very hard to tell apart.

This giant squid (*Architeuthis imperator*) inhabits the North Pacific and is 4.5 metres from the tip of its tail to the tip of its outstretched tentacle.



The squid *Doryteuthis bleekeri*.

The cuttlefish *Sepiella maindroni*.

The Japanese luminous cuttlefish (*Watasenia scintillans*), a small, deep-sea animal that appears seasonally on the south coast of Japan and is important to the fishing industry there. When disturbed, it flashes tiny lights on its body.

NAUTILUSES

Nautiluses are the only existing cephalopods that live in true shells. Although fossil remains show many different species, some with conical shells 4.5 metres long, only three survive today. They have coiled, snail-like shells containing many chambers, but only the largest and most recently formed is inhabited. The others are filled with gas, which allows the shell to act as a float to keep the animal buoyant. Nautiluses have many small, suckerless tentacles, specialised for various functions. Because they live in the depths by day and come up to within 40 metres of the surface only at night, they are rarely seen alive, though their shells are often washed ashore. The early stages of their lives are still a mystery.

Argonauts, though often called paper nautiluses, are not nautiluses at all but rather unusual octopuses. The confusion results from the fact that the female argonaut lives in a thin, papery shell which she constructs to protect her eggs. Males are much smaller than females and have no shells. Argonauts are found near the surface of warm seas, where they feed on plankton.

A paper argonaut (*Argonauta hians*).

The chambered nautilus (*Nautilus scrobiculatus*), shown feeding on a prawn.

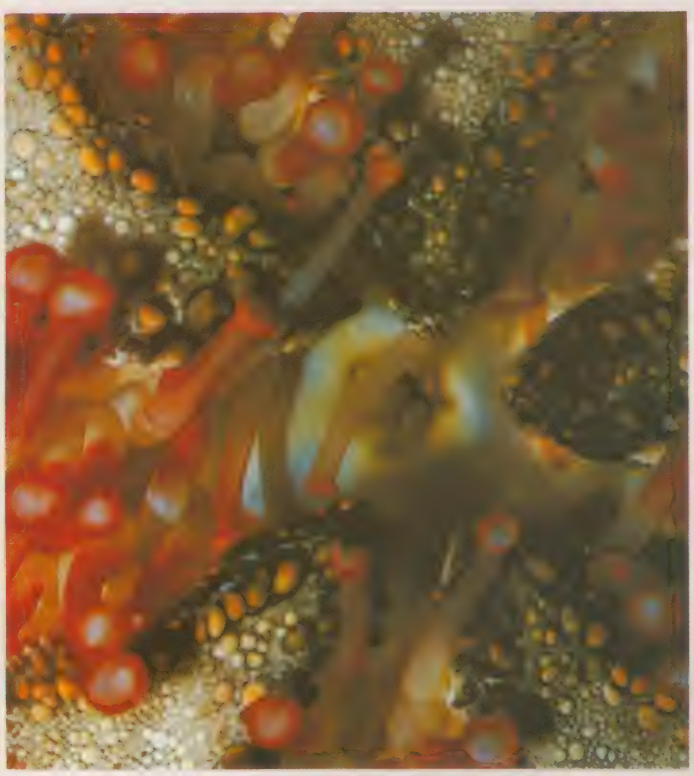
STARFISH AND THEIR RELATIVES

Derived from Greek and meaning "spiny-skinned," the word *Echinodermata* refers to a large group of animals that includes starfish, sea cucumbers and sea urchins. Some, like the starfish, have evenly spaced arms or rays, and all have radially symmetrical bodies supported by small pieces of crystalline calcium carbonate embedded in the skin. Echinoderms are basically simple animals without any distinct head region or distinct respiratory and excretory organs. The larvae are largely planktonic drifters, but the adults of most species live on the bottom. Though essentially primitive, echinoderms do have some complicated organs. One is a complex system of water tubes, often connected to the outside and running through the body. The tubes are connected to large numbers of small, cylindrical projections called tube feet (often provided with a sucker at their tips) used for feeding and for moving around. They are also used as a very simple means of respiration by the exchange of gases through the thin skin of the tube feet. The tube feet can be extended or withdrawn according to the pressure in the system of tubes. Starfish also use their arms to move.

STARFISH

Starfish *(Asteroidea)* have five or more arms and a body with the mouth on the underside and the anus on the upper side. Their tube feet can be extended and used as suckers or withdrawn by the contraction of muscles. Contracting muscles can also block off the connections between different parts of the system of water tubes in their bodies. Starfish are carnivorous, some feeding on animals like molluscs by turning their stomachs inside out, engulfing their food and pouring digestive juices on it. The digested food is then swallowed. Respiration takes place through the tube feet and also through apparatus that protrude from gaps in the skeleton and function as gills. There are separate males and females but these cannot be distinguished externally. Starfish can regenerate a whole animal from a part of the body.

A cushion star (*Culcita*) found in the Indo-Pacific. It does not grow arms.



A close-up of the underside of a starfish, showing the animal's mouth and its tube feet. The multipurpose tube feet are used for eating, respiration and locomotion.

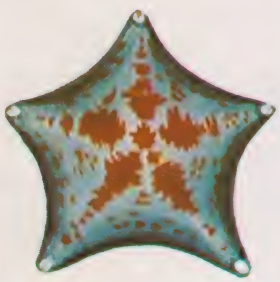
A common starfish (*Asterias amurensis*) from Japan.

The eight-armed starfish *Coscinasterias acutispina*.

The red starfish (*Centonarda semiregularis*) lives on rocky shores in Japanese waters.

The burrowing starfish (*Astropecten scoparius*) lives at 5 to 100 metres in Japanese seas.

Pentagon starfish (Cushion star) (*Cenamaster japonicus*), named for its five-sided shape, lives 600 metres deep in the North Pacific.



The Cushion star *Asterina pectinifera* lives in the Northwest Pacific.

The large crown-of-thorns starfish (*Acanthaster planci*), seen on a coral reef. Feeding on corals, the crown-of-thorns causes great destruction to the reefs. The animal's spines are venomous and can cause considerable pain if they penetrate the skin.

BRITTLE STARS AND BASKET STARS

Brittle stars, or serpent stars *(Ophiuroidea),* have small, disc-shaped bodies with five long arms that look like lizard tails. They move around with a snake-like action of their strong arm muscles. Brittle stars are the most abundant of all echinoderms—one English species carpets certain sea bottoms with as many as 100 million animals to one square kilometre. Basket stars *(Gorgonocephalidae)* are unusual brittle stars, although they more closely resemble feather stars. They have multibranched, often tightly coiled arms. The name "gorgonocephalid" is derived from the basket star's resemblance to the Gorgon, a monster from Greek mythology who had writhing snakes for hair.

A Japanese basket star (*Gorgonocephalus caryi*) attached to a sea fan.

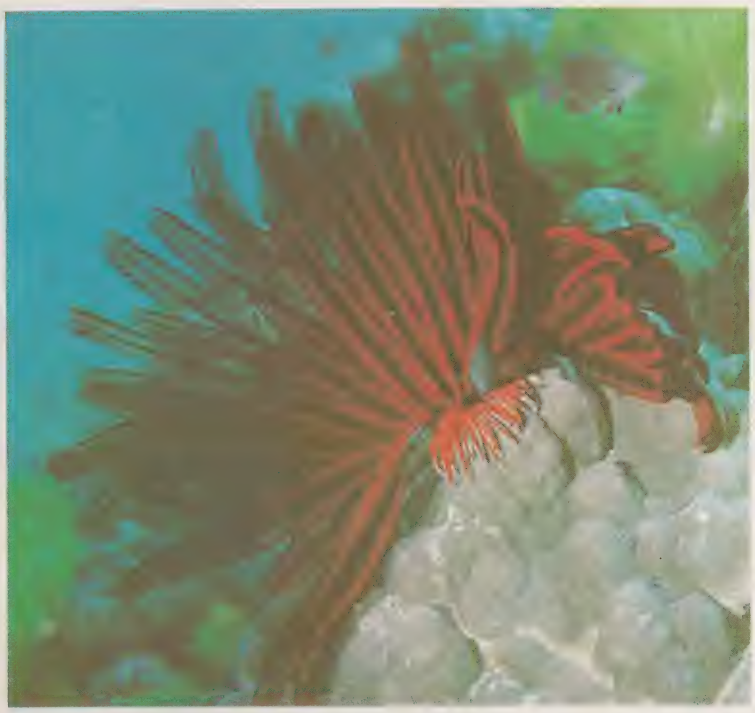
A beautiful basket star (*Astrophyton muricatum*) from the Caribbean.

Brittle stars (*Ophiothrix fragilis*) blanket a section of sea bed.

FEATHER STARS

Feather stars, or sea lilies *(Crinoidea),* the most primitive echinoderms, are animals that look like flowers. Long ago, crinoids on stalks up to 20 metres long covered the sea bottom, but most present-day species are free-swimming creatures that lack stalks. Their long, jointed and highly flexible arms are branched, and they often swim by waving these arms up and down. Short, curved, rootlike structures on the underside called *cirri* are used to hold on to seaweeds or rocks. Feather stars catch small plankton and particles of food in streams of mucus that are carried along ciliated grooves in the arms to the mouth. Fertilisation takes place in the water, and the young go through a planktonic larval stage before becoming adults.

A feather star.



This blood-red feather star (*Humerometra robustipinna*) of the Indo-Pacific.

This feather star (*Cenometra bella*) is attached by its cirri to a red seawhip.

SEA CUCUMBERS

Sea cucumbers *(Holothuroidea)* take their name from their soft, cylindrical bodies, which do resemble cucumbers. Most species lie on their sides on the ocean bottom, thus developing a definite upper and lower surface to the body; some with tentacles are able to burrow as well as travel by contracting their muscles like a worm. All species that have tube feet are able to walk slowly by means of the tube feet's tiny suckers. Sea-cucumber tentacles are specially modified tube feet that surround the animal's mouth. They are used to trap small particles of food and thrust them into the mouth. The internal skeleton of the sea cucumber is so reduced as to consist only of minute crystalline bits in the skin. Certain species eject a long stream of white fluid that rapidly congeals into a sticky mass and serves to entangle a would-be predator. Others can expel their internal organs—perhaps to temporarily satisfy a predator while the sea cucumber makes its escape. The organs are later regrown. Some sea cucumbers, particularly those called trepang, or bêche-de-mer, are used, especially by the Chinese, for making soup.

The mouth of the sea cucumber is shown at the top. Its tube feet can be seen clearly on the body.

This edible sea cucumber (*Cucumaria*) is dried and eaten by the Chinese in Southeast Asian countries.

The purple sea cucumber (*Polycheira rufescens*) lives under rocks on Pacific subtropical shores.

The edible Japanese sea cucumber (*Stichopus japonicus*).

The very common black sea cucumber (*Holothuria atra*), which lives on coral flats. When disturbed the animal emits a white fluid that entraps its enemy.

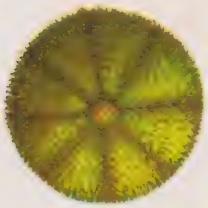
This long and slender sea cucumber (*Synapta*) is found on coral sand flats near the low-tide mark. It can reach a great length by contracting its circular muscles.

A sea cucumber feeding. Its tentacles trap small food particles and transfer them to its mouth.

Pentacta tuberosa (right) is a colourful species of sea cucumber from coral reefs in Southeast Asia. Three rows of yellow tube feet can be seen on its white body. At left is a clam that has opened its shell, making its green mantle visible.

SEA URCHINS

Sea urchins *(Echinoidea)* have spherical, heart-shaped or flattened bodies with a crystalline, chalky skeleton of flattened plates closely fitted together like a mosaic and lying just under the skin. Though lacking arms, they possess five double rows of tube feet and long spines that are capable of moving on ball-and-socket joints. The tube feet and spines allow the urchin to creep over rocky surfaces or, in some species, through the sand. Spines of a few species contain poison glands; the sharp, brittle spines of the needle-spined urchin are a constant hazard for swimmers and skin divers—piercing the skin easily and breaking off, they discharge a mild venom that, though not dangerous, can be very painful. Sea urchins may be plant- or meat-eaters but will scavenge for almost anything when food is hard to find. In some the mouth on the underside of the body contains teeth that can be projected to scrape algae and other food off rocks and are even capable of excavating hiding places in rock or coral. In some areas of the world, parts of sea urchin are a great delicacy.



This edible sea urchin (*Hemicentrotus pulcherrimus*) lives in shallow waters around Japan.

A helmeted sea urchin (*Colobocentrus mertensi*), which takes its name from its shape.

This heart urchin (*Schizaster lacunosus*) lives in a little chamber at the end of a burrow which it digs in the sand with its fine spines. It feeds on small particles.

The sand dollar (*Staphechinus mirabilis*) lives in sand in shallow waters. It has a slightly irregular shape well adapted to burrowing.

A group of needle-spined sea urchins (*Diadema setosum*) on the sea bottom. The beautiful jet-black animals are found on coral reefs throughout the tropics.

The slate pencil sea urchin (*Heterocentrotus mammillatus*) is found all over shallow tropical seas. Its twelve-centimetre-long spines may be as much as one centimetre thick.

The keyhole urchin (*Astriclypeus manni*) lives in sand. It has an extremely flattened, disclike body with slits useful in burrowing.

The sea urchin *Tripneustes gratilla*.

COMB JELLIES

Comb jellies *(Ctenophora)* are small animals that resemble delicate, glasslike jellyfish, but they are not coelenterates. Most drift freely in the water and are important elements of plankton. The name "comb jelly" comes from eight rows of tiny, comblike structures on their bodies that are actually rows of cilia matted together. These combs beat in the water to propel the animals forward. Some species have two long tentacles that can be withdrawn into the body. Comb jellies feed on other plankton that they catch with special sticky cells either on their tentacles or on the body surface itself in species without tentacles. Many comb jellies are luminous, and some of them produce beautiful brilliant flashes of colour at night.

Swimming with wavy movements, the comb jelly called Venus's girdle (*Cestus veneris*) looks like a long, transparent belt.

Eurhamphaea vexilligera, displaying the typical eight rows of combs.

Two thin tentacles extend from the body of this beautiful comb jelly (*Hormiphora palmata*).

Seemingly floating in space, a comb jelly moves in the water.

MOSS ANIMALS

Moss animals *(Bryozoa)* are small, colonial bottom dwellers that live attached to a variety of surfaces in the water: rocks, seaweeds, other animals like sponges, twigs, pilings—even the hulls of ships. They range in size from about 1 to 1,000 millimetres. Some colonies look like flat sheets of moss; others grow in fanlike or twiglike shapes. Each individual in a moss-animal colony is surrounded by a tough horny or chalky outer covering and has a mouth surrounded by a large number of tentacles. Tiny cilia on the tentacles produce water currents to direct minute food particles into the animal's mouth. When disturbed the animal retracts its tentacles.

Attached to the skeleton of a dead hydroid, the moss animals (*Lichenopora*) in this tiny colony extend their many tentacles.

Looking like a small tree with many branches, this moss-animal colony (*Bugula neritina*) is composed of little brown animals.

LAMP SHELLS

The earliest fossil-bearing rocks indicate that lamp shells *(Brachiopoda)* are among the most ancient of all animals, dating back more than 550 million years. One species, the *Lingula,* shows no recognisable changes from its very distant ancestors and is thus called a living fossil.

Typical lamp shells get their name from their shape, said to resemble that of early Roman oil lamps. Like bivalve molluscs, they have soft bodies protected by two shells, or valves, that are hinged together, but they are not related to bivalves. Whereas the two shells of the bivalve are of the same size and shape, the lamp shell has one shell that is larger than the other and which ends in a tubular, projecting beak. A long, fleshy stalk protrudes through a hole in this beak and serves to anchor the animal to the sea bottom. The stalks of a few lamp shells like *Lingula* are capable of movement, aiding the animal in burrowing in mud or sand. Some lamp shells have strong, limy shells with long stalks; others have horny shells with fleshy, footlike projections. Lamp shells feed by opening their shells and drawing water currents in by beating their cilia, which are attached to an organ that filters food from the water.

The larger shell of the lamp shell *Laqueus rubellus*, found in the deeper oceans.

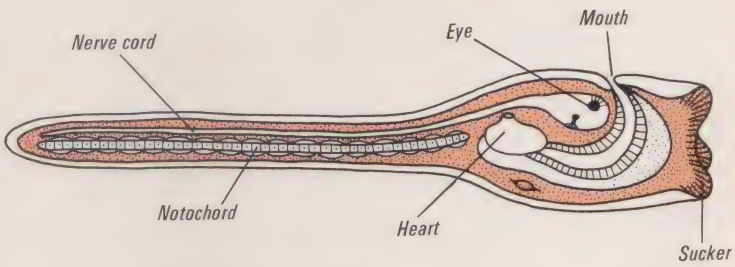
Lingula unguis lives in sand or mud, using its long stalk as an anchor. When the animal is disturbed, the stalk shortens to pull the shell down into the mud.

The larger shell of a lamp shell (*Coptothyris grayi*), showing the beak and the hole through which its stalk projects.

SEA SQUIRTS

Found in shallows as well as in fairly deep water, sea squirts *(Tunicata)* live attached to the sea bottom or to objects like rocks, seashells, the backs of certain crabs, pier pilings and the hulls of ships. They are shaped like hollow jars and get their name from the fact that they contract and squirt water through their siphons when touched.

Though sea squirts look somewhat like sponges, their appearance is deceptive, for they are related to, and in fact may be ancestors of, the higher animals with backbones—including humans. In the larval stage, the sea squirt is free-swimming and looks like a tadpole. Running along the underside of the larva's nerve cord is a *notochord,* a gelatinous rod that is a kind of primitive backbone. This rod is also found in fish, animals with true backbones. In the dramatic transition from larva to adult, the notochord disappears, absorbed into the body after the larva has attached itself to something by a sucker that is located on the front of its head.



A sea squirt in the larval stage with its primitive backbone, the notochord, still intact.

The adult sea squirt is protected by an outer covering called the *tunic.* One end of its body is attached to the sea bottom or another object by a stalk. At the other end are two siphons, one—developed from the tadpole larva's mouth—to draw water into the body cavity, the other to expel it. As water passes through its mouth the sea squirt removes the food (plankton) and the oxygen from it.

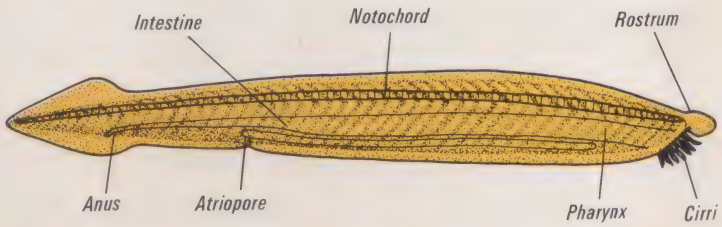
The inlet and outlet siphons of the sea squirts (*Clavellina picta*) in this Caribbean colony are clearly visible.

These beautiful purple Southeast Asian sea squirts have star-shaped siphons.

THE LANCELET

The lancelet *(Amphioxus)* is an elongated, eel-like animal that stands between the two great groups that make up the animal kingdom: invertebrate and vertebrate. Although it has no distinct head, the lancelet has the beginnings of eyes, a mouth, a fin extending along most of its body and a notochord that is well developed and can be regarded as the evolutionary beginning of the true backbone found in all the vertebrates. The lancelet is believed to be related to the ancestors of the vertebrates and thus bridges the gap between the sea squirts and the most primitive fishlike vertebrate, the jawless fish.

The lancelet usually lies buried in the sand of coastal waters by day with only its mouth exposed. Whisker-like tentacles covering the mouth filter out food particles from the water. At night the lancelet emerges to swim with fishlike movements of the body.



The lancelet lies buried in sand, its mouth exposed to feed.

The Indo-Pacific lancelet *Branchiostoma belcherii.*

THE FISH WORLD

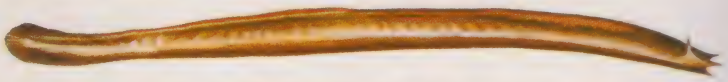
Although amphibians, reptiles, birds and mammals are also found in the waters, the vast majority of aquatic animals with backbones are fish. Fish are cold-blooded animals that propel their streamlined bodies through the water by moving their fins. Though possessing only moderately good vision, they have a keen sense of smell and hearing, and their sensitive lateral line organs (see page 16) can detect vibrations. Fish breathe with gills. Fertilisation of their eggs usually occurs outside the body. There are three classes of fish—jawless fish, cartilaginous fish and bony fish—but most fish are bony.

JAWLESS FISH

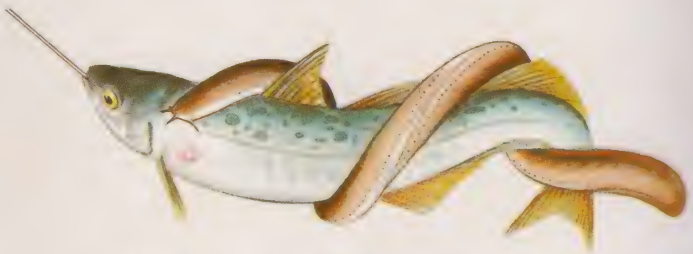
Most primitive of all living vertebrates, members of this group *(Agnatha)* are distinguished from other vertebrates by their lack of jaws. The only surviving species of this ancient class are lampreys and hagfish. Jawless fish have mouths with a cup-shaped sucker and horny teeth; cylindrical, scaleless bodies; and a skeleton made of cartilage, a flexible and translucent material. Unlike those of other fish, the gills of jawless fish are contained in a series of separate muscular pouches. Lampreys have seven pairs of such gill pouches, hagfish from six to fourteen pairs. Jawless fish are semi-parasitic, feeding on other fish as well as on certain worms and other invertebrates. They also scavenge dead fish.

HAGFISH

Hagfish *(Myxiniformes)* flourish on the bottom of cold and temperate seas where they burrow into the mud. Surrounded by three or four pairs of tentacles, their small mouths have a tongue with two rows of horny, rasplike teeth. All hagfish are hermaphrodites (see page 20), and their eggs develop directly into small fish without going through a larval stage. Adult hagfish feed by burrowing into dead or dying fish, eating the flesh and insides and leaving only the bones and skin. As many as 123 hagfish have been found in the body of a single fish.



The North Atlantic hagfish (*Myxine glutinosa*).



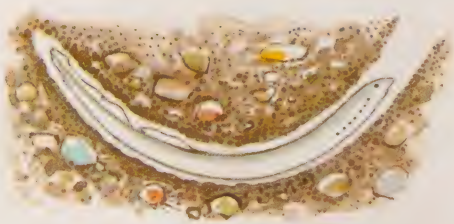
A hagfish attacks a hooked fish by twisting around its victim's body and then boring into it.

LAMPREYS

Lampreys *(Petromyzontiformes)* are eel-shaped animals about 30 centimetres to 1 metre in length, found in the temperate zones of both hemispheres. They have no paired fins. Their large sucking mouths are full of horny teeth that are used to make a hole in the fish upon which lampreys feed. After opening the hole, lampreys attach themselves to their victims and suck out the blood, in the process producing a substance that prevents clotting. The life history of lampreys usually has two distinct stages. Larvae live buried in the mud in freshwater streams and rivers feeding on tiny organisms until they are ready to swim downstream to their second home, the sea.

The sea lamprey (*Petromyzon marinus*) lives on both sides of the Atlantic. It migrates from the ocean up rivers to spawn.

The lamprey attaches itself to a fish with its sucker mouth.



The lamprey egg develops into a blind and toothless larva that lives in a U-shaped tunnel in the river bed, feeding on minute creatures that it filters from the water.

After preparing a nest in the river bed, male and female lampreys mate by entwining and moving backward and forward to shed their eggs and sperm. After mating they die.

The cup-shaped mouth of the lamprey is armed with many horny teeth. Inside, the tongue is also equipped with horny teeth.

CARTILAGINOUS FISH

Cartilaginous fish *(Chondrichthyes)* form an important class of fish that includes sharks, rays and chimaeras. Descendants of animals that swam the seas more than 100 million years ago, members of this class are often called living fossils and are therefore of particular interest to scientists. Cartilaginous fish get their name from their skeletons, made not of bone but of a firm white substance called cartilage. Their skin is covered with tiny, toothlike scales, giving it a texture like that of sandpaper, and, unlike bony fish, each gill has a separate opening to the outside called a *gill slit*. While sharks take in water for respiration mainly through the mouth, most species also use an opening behind each eye called a *spiracle;* rays use only the spiracles. The sharp teeth of most cartilaginous fish are modified scales that are continuously being formed in the slit-shaped mouth.

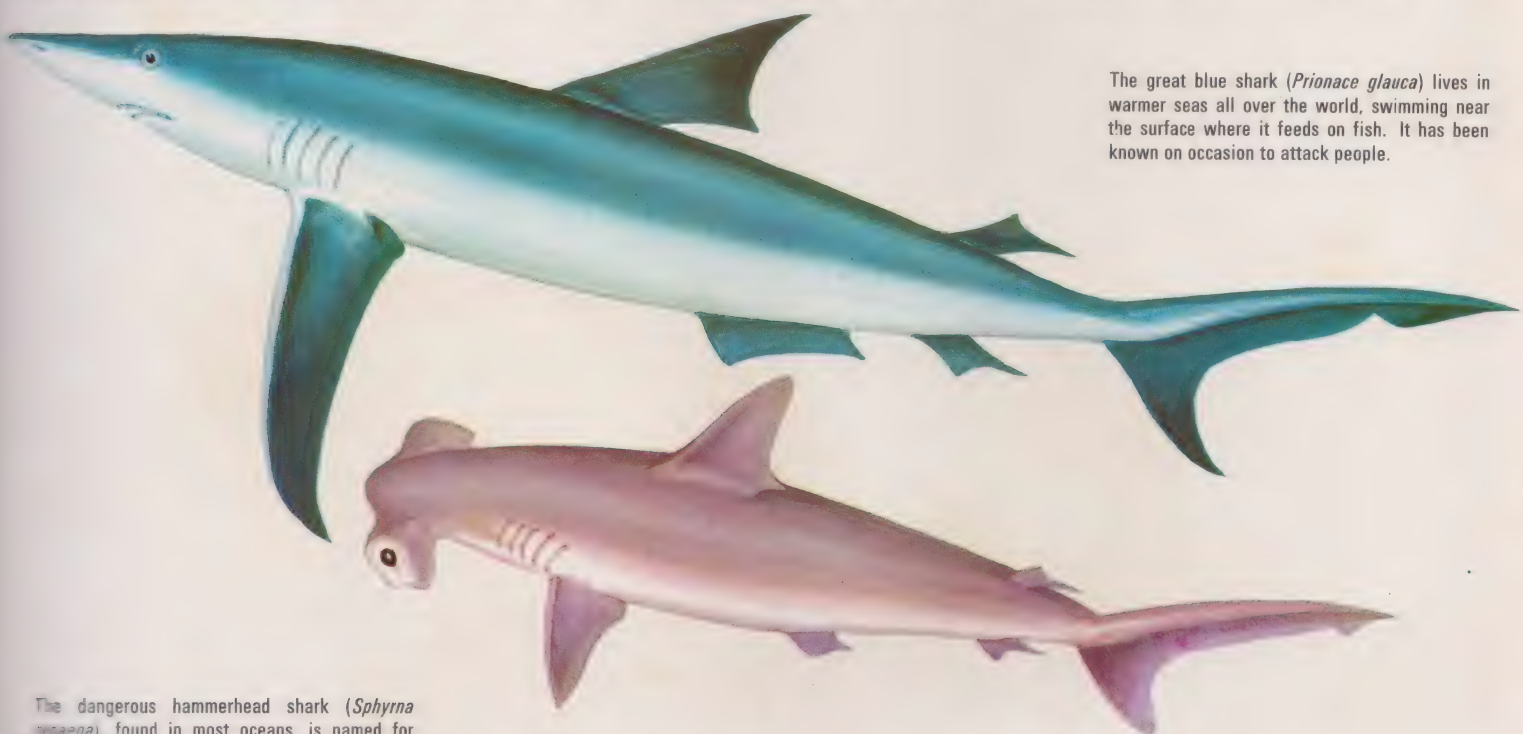
All species produce large, yolk-rich eggs that are fertilised internally through special organs called *claspers* located along the inner edges of the male's pelvic fins. Many bear their young alive, but some lay the fertilised eggs—enveloped in horny capsules—on fixed objects on the sea bottom.

A mermaid's purse, the large, flexible egg capsule of a swell shark, fixed to seaweeds by small tendrils at each corner.

A leopard shark (*Triakis scyllia*) on a coral reef. The five gill slits and the claspers behind the pelvic fins can be seen.

SHARKS

A source of fear and of fascination all over the world, sharks *(Pleurotremata)* vary in size from the dogfish, less than one metre long, to the huge whale shark, which at 18 metres is the world's largest fish. Most are predators, feeding on fish and other marine animals with jagged, razor-sharp teeth that are constantly being replaced as they become lost or damaged. Sharks have paired fins that act like hydrofoils to lift their bodies while swimming through the water. They breathe through five to seven pairs of gills, absorbing oxygen from the water taken in and then passed out through slits on the side of the head. They have one of the keenest senses of smell in the animal kingdom: Tiny amounts of certain substances like blood can attract sharks from great distances. Certain shark species, especially those of large size with large, cutting teeth, are known as man-eaters—the most dangerous being the great white shark. But size and danger do not necessarily go together—the giant whale shark, despite its enormous size, is quite harmless. It is content to cruise the oceans and feed on the small fish and plankton that it filters from the water with a gridlike tissue at the inner end of the gill slits.



The great blue shark (*Prionace glauca*) lives in warmer seas all over the world, swimming near the surface where it feeds on fish. It has been known on occasion to attack people.

The dangerous hammerhead shark (*Sphyrna zygaena*), found in most oceans, is named for the shape of its head, each end of which carries an eye and a nostril.

A group of nurse sharks (*Ginglymostoma cirratum*). Common in the West Atlantic, they are often found in groups on the sandy sea bottom. Nurse sharks bear their young alive. They may attack swimmers.

The sawfish (*Pristis pectinatus*) is a sharklike ray named for its long, flat snout edged with strong teeth. The saw is used in feeding, either to strike fish in schools or to dig in the sea bed for bottom-dwelling animals like molluscs.

The goblin shark (*Scapanorhynchus owstoni*) is rare. It was known only from fossil teeth until one was caught off Japan in 1898.

Weighing many tonnes, the gentle whale shark (*Rhincodon typus*) is the largest fish in the world. It is found in warm, tropical seas.

Deadliest of the man-eaters, the great white shark (*Carcharodon carcharias*) can grow to a length of 12 metres. It is found near the surface of warm seas but also ranges into cooler waters.

RAYS

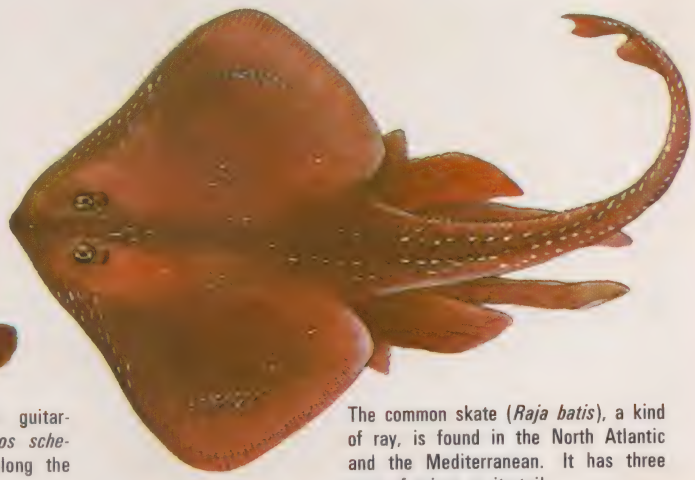
Resembling strange undersea birds of prey, rays *(Hypotremata)* move slowly through the water flapping their huge, winglike pectoral fins. They have flattened bodies and long, slender tails that in some species bear one or more saw-edged, poisonous spines. The eyes and spiracles are on top of the head, but the mouth, nostrils and gill slits are on the underside.

Rays are unaggressive and do not prey on humans, but since many are sluggish bottom dwellers that often lie partly buried in the sand or mud, they are easily stepped on by unwary bathers and divers. The results can be unpleasant if the disturbed animal turns out to be one of the more dangerous species: The stingray can produce painful, jagged wounds—sometimes resulting in death—by whipping its muscular, bony tail to drive poisonous spines into the intruder. Electric rays can produce shocks from modified muscle fibres called *electroplates* that are capable of stunning a person.

Largest of all the rays is the Atlantic manta, a fearsome-looking but harmless giant that can reach more than seven metres in length and weigh considerably more than 1,000 kilograms. The manta swims near the surface, content to feed on plankton and other small animals, which it guides into its mouth with two hornlike projections of the pectoral fins that extend from its head. It is known for its spectacular leaps out of the water—often more than four metres into the air—probably in an attempt to rid itself of annoying parasites. Young mantas have occasionally been born in the air during one of their mothers' acrobatic performances.

The Atlantic manta, or devil ray (*Manta birostris*), is the largest of all the rays. Though not aggressive, the manta has the power to smash a boat.

A shovel-nose guitarfish (*Rhinobatos schegeli*) moves along the sandy bottom.



The common skate (*Raja batis*), a kind of ray, is found in the North Atlantic and the Mediterranean. It has three rows of spines on its tail.

The southern stingray (*Dasyatis americana*) digs for food in the soft bottom of the Caribbean. Its venomous tail makes up half its total length.

A Japanese electric ray (*Nerke japonica*), found on the bottom of shallow waters in the oceans in the vicinity of Japan.

CHIMAERAS

Chimaeras, also called ghost sharks *(Bradyodonti)*, are unusual cartilaginous fish found in temperate to cold waters of all oceans. They resemble sharks in many ways, but unlike sharks and rays, they have a single external gill opening covered by a bony gill cover as in the bony fishes. Males have claspers similar to those of sharks and rays but, unique among fish, also possess supplementary clasping organs on the forehead and in front of each pelvic fin. Chimaeras are further characterised by slender, whiplike tails—earning some species the name ratfish—and large, poisonous spines in the front part of the first dorsal fin. Some have extended, pointed snouts. Chimaera teeth consist of grinding plates with which it crushes the shells of the invertebrates on which it preys.

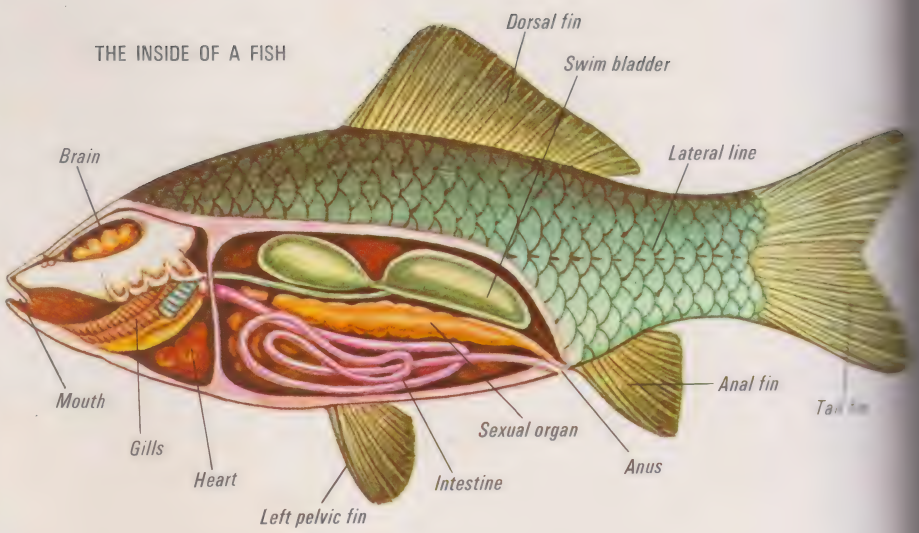
The long-snouted chimaera (*Rhinochimaera atlantica*) measures about 1 metre and lives in the Atlantic Ocean.

A chimaera (*Chimaera monstrosa*) that lives in the Atlantic and the Mediterranean.

BONY FISH

Bony fish *(Osteichthyes)* form by far the largest class of fish. They can be subdivided into two groups characterised by fin structure: the lobe-finned fish and the ray-finned fish. Fish in both groups have bony skeletons and both paired and median fins; their skin is usually covered with circular scales that are thin, flexible and bony. Ridges in the scales may reveal the age of the fish. Bony fish have a bony gill cover on each side of their bodies to protect the gill chamber with its five gill arches. Though lungs are present in some primitive bony fish, in most species the lungs have been modified into the swim bladder. The eyes are usually at the side of the head, giving the fish a wide field of vision both to the front and to the rear.

In most species of bony fish, eggs from the female are fertilised outside the body by the male. The eggs hatch into tiny fry that are usually nourished by the egg yolk attached to their bellies until they are ready to find their own food.

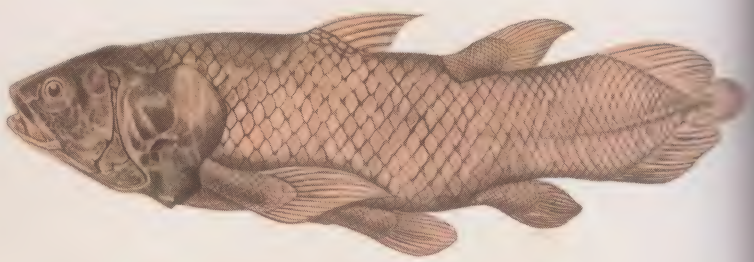


LOBE-FINNED FISH

Lobe-finned fish *(Sarcopterygii)* have bony-fin skeletons that are completely covered with muscle so that their fins have a fleshy, rounded appearance. They are extremely interesting to scientists because they include the ancestors of the first vertebrates to move on land. Far fewer in number than ray-finned fish, their only living survivors are the coelacanth and three groups of lungfish. The first amphibians were probably descended from air-breathing lobe-finned fish that, according to the fossil record, began as early as 370 million years ago, in the Upper Devonian Period, to move out of lakes, streams and ponds that were drying up. These primitive creatures probably crawled with their fins in much the same way as amphibians use their legs.

COELACANTHS

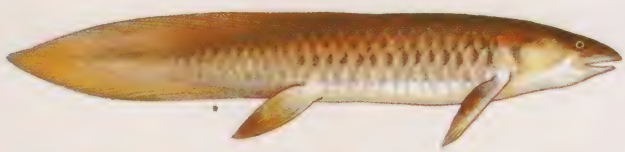
Thought to have died out some 70 million years ago until one was caught off South Africa in 1938, the coelacanth *(Crossopterygii)* is the world's oldest living unchanged vertebrate. Finding this fish was the most important discovery of a supposedly extinct animal ever made. Appearing some 200 million years before the dinosaurs, this remarkable living fossil has undergone little change in 300 million years. For this reason scientists study the coelacanth for valuable insights into vertebrate evolution. Coelacanths are characterised by large, blue, enamelled scales, a tufted projection at the end of the tail and fleshy paddle-shaped fins attached by "stalks" to the body. Since it is believed that the coelacanth uses paired pectoral and pelvic fins to crawl on the ocean floor, the study of this animal may give us more information about how fins became limbs.



The long, stocky coelacanth (*Latimeria chalumnae*).

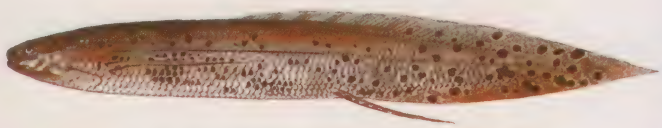
LUNGFISH

Lungfish *(Dipnoi)* belong to an order of fish possessing both lungs and gills. The group dates back almost 400 million years. In Australia there are two species of one kind of lungfish with four species of a different kind in South America and Africa. In prehistoric times, when the earth's ponds and streams started to dry up, lungfish were able to survive by breathing air and travelling from puddle to puddle on paddle-like fins. Later they acquired the ability to remain dormant in mud, waiting for seasonal rains. Today certain lungfish can live out of water in mud for up to four years by secreting a leathery cocoon around their bodies and living on energy stored in muscle tissue.



The Australian lungfish (*Neoceratodus forsteri*) is found in only two small rivers in Queensland. It has large, overlapping scales and paddle-like paired fins.

The eel-shaped South American lungfish (*Lepidosiren parasoxa*) has small scales hidden under a soft outer skin, and slender fins. It sleeps in the mud during the dry season.



During the months of the dry season, the West African lungfish (*Protopterus annectens*) curls up in a muddy hole at the bottom of a river.

RAY-FINNED FISH

Most fish are ray-finned. There are some 25,000 species of ray fins *(Actinopterygii)*, including all the living bony fish except lungfish and coelacanths. Ray-finned fish take their name from their fanlike fins. These are composed of thin membranes or outgrowths of skin supported by flexible bony or cartilaginous rods called rays. These rays are of two general types: stiff, spiny rays and the more pliant and flexible soft rays. Ray-finned fish include two primitive groups, the *Chondrostei* and *Holostei*, but most belong to a huge group of modern fish, the *Teleostei*.

Related to the bichir, the reed fish (*Erpetoicthys calabaricus*) looks more like a snake than a fish. It has no pelvic fins.

BICHIRS

Found only in tropical Africa, bichirs *(Brachiopterygii)* are archaic fish that show characteristics of both lobe-finned and ray-finned fish. Like the lungfish, they have a lunglike breathing organ, and their paddle-like pectoral fins resemble the lobe-finned group. Their skull structure, however, is similar to that of the ray fins. Bichirs are easy to distinguish from all other fish because of the series of dorsal fins on their backs, each supported by a single spine.

Week's bichir (*Polypterus weeksi*) is found in tropical African rivers and swamps. It has an armour-like covering of diamond-shaped scales and fleshy, paddle-shaped fins.

STURGEONS AND PADDLEFISH

Sturgeons and paddlefish are the only survivors of the once numerous and most primitive group of ray fins, the *Chondrostei*. Though some bone is present, their skeletons are still composed mainly of cartilage. Sturgeons have soft whiskers under the snout called barbels and toothless sucking mouths on the underside of the head. In spring they move upriver to spawn. Later the young migrate to the sea. The delicacy caviar is made from the eggs of the sturgeon, particularly those from the Caspian Sea. Paddlefish, with their long, spadelike snouts and huge mouths, are freshwater relatives of the sturgeon.

The paddlefish (*Polyodon spatula*) of the Mississippi River in the United States uses its snout to stir up minute organisms on the river bottom, which it then catches in its wide mouth.

Two common sturgeons (*Acipenser sturio*). The sturgeon is found on both sides of the Atlantic Ocean and grows to about three metres.

BOWFINS AND GARS

Bowfins and gars are the sole survivors of the *Holostei*, a group of primitive ray fins a bit more advanced than the *Chondrostei*. Their skeletons contain more bone than those of sturgeons and paddlefish, and their fin structure is more efficient for swimming. Bowfins and gars inhabit fresh waters in North America, though some gars do venture into brackish or even salt water. Both have air sacs that can be used for breathing. Bowfins are characterised by their long dorsal fin and strong teeth; gars by a beak formed from the face, jaws that carry very sharp teeth and a body encased in an armour of thick, diamond-shaped scales. The huge alligator gar of the southern United States is one of the largest of all freshwater fish.

The huge alligator gar (*Lepisosteus spatula*) can grow to a length of three metres.

The bowfin (*Amia calva*) inhabits lakes and rivers in North America.

The long-nosed gar (*Lepisosteus osseus*) uses its powerful teeth to catch its prey, usually smaller fish.

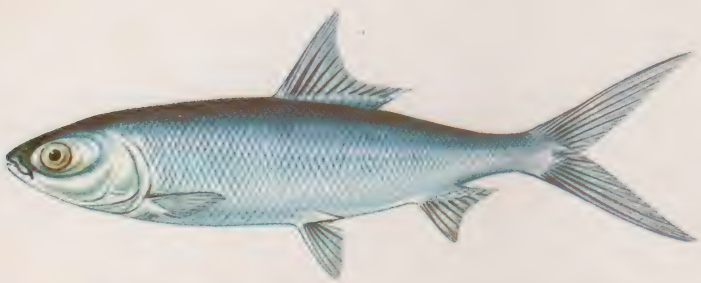
MODERN FISH

The modern ray-finned fish *(Teleostei)* are the most successful group of fish in history and include most of the species we know today. They are found in every part of the world of water and range in form from the familiar salmon and perch to the snakelike eel; the huge, round ocean sunfish and the weird seahorse. All the fish here and on pages 69–103 are members of this group.

THE HERRING GROUP

The herring group *(Clupeoidea)* includes some of the most numerous and commercially valuable of all fish, such as herring, anchovies and sardines. These fish have a short upper jaw and either poorly developed teeth or no teeth at all. They live in large shoals in the open sea, migrating every year to follow their planktonic food and to spawn. Herring, anchovies and sardines are eaten in a variety of ways—fresh, dried, salted, pickled, smoked or canned. Some species are also used as bait, made into fish meal for animal feed or processed into oil for use in paint, varnish, linoleum and even margarine. Two of the world's most important fisheries are the anchovy industry of Peru and the herring industry of Europe.

Anchovies like *Engraulis japonica* resemble small herring and can easily be distinguished by their short, thin lower jaw and large mouth.



The milk fish, or salmon herring (*Chanos chanos*), generally inhabits the warmer waters of the Indian and Pacific Oceans but moves into inshore waters to spawn. An important food fish, it is farmed in huge seaside ponds in the Philippines.

THE SALMON GROUP

Fish like salmon, trout and char *(Salmonoidea)*, famous for their excellent taste, are also favourites of sportsmen because of their fighting qualities. They are characterised by wide, gaping mouths—with teeth that are well developed for eating fish and crustaceans—and a small, fatty fin called the *adipose fin* on the back behind the dorsal fin. Salmonoids are strong swimmers. Many species spend most of their lives in the sea but then often travel great distances upstream to breed in fresh water. The king salmon, for example, swims 3,500 kilometres up Canada's Yukon River to reproduce.

The king salmon (*Oncorhynchus tschwytscha*) of the North Pacific is the largest fish in the salmon group.

HERRING, SALMON AND THEIR RELATIVES

Clupeiformes, the most primitive order of modern ray-finned fish, includes herring, salmon, pike, bony-tongued fish, mormyrids and many others. They have soft-rayed fins, and the pelvic fins are placed far back, away from the pectoral fins. Though a few species live in the deep sea, most are found in shallow seas or fresh water. Many are important food sources.

This sardine, or pilchard (*Sardinops melanosticta*), is about 25 centimetres long and lives in the coastal waters of the North Pacific.

This round herring (*Etrumeus micropus*) is found in the open sea near Japan.

The common herring (*Clupea harengus*) swims in enormous schools in open North Atlantic waters.

The red salmon (*Oncorhynchus nerka*) is one of the most delicious food fish among salmon and trout.

The male pink salmon (*Oncorhynchus gorbuscha*) is the most abundant salmon in the North Pacific. Male salmon develop a humped back and hooked jaws during the breeding season.

The brown trout (*Salmon trutta*) is a native of clear mountain streams in Europe. An important food and sport fish, it has been introduced into other lands.

The American brook trout (*Salvelinus fontinalis*) flourishes in the cold rivers of eastern North America. Like the brown trout it has been introduced to other parts of the world.

This lake trout (*Oncorhynchus rhodurus*) flourishes in Japan.

A popular Japanese food fish, the ayu (*Plecoglossus altivelis*) is related to the salmon. Adult ayu live in the sea, returning to rivers to spawn. There—in a classic example of territorial behaviour—each fish stakes out and defends a small feeding area.

Three varieties of the rainbow trout (*Salmo gairdneri*) native to North America.

BONY-TONGUED FISH

Bony-tongued fish *(Osteoglossoidea)* are a small group of primitive tropical river fish characterised by a prominent bone resembling a tongue where the gill arches join together. The group appears to have died out in most places and today is found only in parts of tropical South America, Africa, Southeast Asia and Australia. Bony-tongued fish are covered with large, mosaic-like scales. Some exhibit interesting behaviour, such as the featherback, which can swim backward and forward by wavelike movements of its long anal fin. The biggest member of the group—and largest of all true freshwater fish—is the pirarucu of South America's Amazon River.

The mouthbreeding arawana (*Osteoglossum bicirrhosum*) is found in the fresh waters of northern South America. Its mouth slit is almost vertical, and there are two barbels on its chin. It can leap out of the water to catch insects.

The knife fish *(Notopterus chitala)* is a bony-tongued fish that lays its eggs on submerged *logs*. The male defends them and keeps them clean. Its habitat is in the seas around East Africa and India.

The kelesa (*Scleropages formosus*) is a primitive bony-tongued fish found in the rivers of Southeast Asia.

The huge pirarucu (*Arapaima gigas*) grows up to 3.5 metres in length. It can make a very loud noise by blowing air out of a swim bladder that serves as a lung.

The viper fish (*Chauliodus sloanei*), found at depths of 500 to 2,300 metres, has light-producing organs on its belly and long, needle-like teeth. Viper fish can swallow fish larger than themselves.

The elephant-trunk mormyrid (*Gnathonemus curvirostris*) uses its long, sensitive snout to probe for worms and insect larvae on the muddy bottom of Africa's Zaire River. Electric organs help it find its way in the dark waters.

Related to the viper fish, the slickhead (*Dolichopteryx*) has stalked eyes and extended pectoral fins. It is abundant in deep seas.

The pike (*Esox lucius*) lies in wait among water plants ready to snap up a fish with its duckbilled jaws and sharp teeth. Found in North America, Europe and northern Asia, pike may eat ducks and small mammals that live in the water.

The bristlemouth (*Cyclothone signata*) is one of the most abundant of deep-sea fish. The small green dots are luminous organs.

The African butterflyfish (*Pantodon buchholtzi*) has distinctive fins and markings. Living near the surface, it leaps out of the water to catch insects, especially at night. It then spreads its pectoral fins to glide back down to the water.

LANTERN FISH AND LIZARD FISH

Lantern fish *(Myctophidae)*, found in deep tropical waters by day, display vertical migration by moving upward toward the surface waters at night. They are small and move about in schools, displaying luminous organs on their heads and bodies. Females of each species have a particular pattern of lights that is recognised by males of the same species, thus ensuring that the right fish will be attracted to each other at mating time. Lantern fish either have no swim bladder or have one filled with fat to withstand the pressure at great depths.

Lizard fish *(Synodontidae)* take their name from their lizard-like heads. They live in shallow waters, sometimes partially buried in the bottom, resting on the pelvic fins. Their body markings match those of their surroundings.

This lantern fish (*Diaphus coeruleus*) has neat rows of luminous organs on its belly.

The lizard fish (*Saurida undosquamis*) lives in shallow Indo-Pacific waters.

CARP, CHARACINS AND CATFISH

The 5,000 species of *Cypriniformes* include the carp family as well as loaches, characins, electric eels and catfish. Except for a few marine catfish, all live in fresh water and are found in every continent except Australia and Antarctica. Members of this order differ greatly in form, but all have pelvic fins far behind their pectoral fins and a unique sensing device—the *Weberian ossicles*. Four bones of the backbone modified to form a chain, the Weberian ossicles connect the swim bladder to the inner ear. This device is thought to help the fish detect sounds by vibrations transmitted along the ossicles.

THE CARP FAMILY

About 1,500 species of the carp family *(Cyprinidae)* live in the fresh waters of most countries and are known by a variety of names: minnows, chubs, barbs, daces, bleaks, bream, bitterlings and more. All of them feed on plants, thrusting forward their toothless jaws to suck food to the back of the throat where they have grinding teeth.

Carp have long been valued for food and pleasure, especially in East Asia. They have been bred in China for almost 2,500 years both as food and ornamental decoration; the Japanese have produced many varieties of the radiant, multicoloured and very expensive nishiki carp to grace garden pools. In Europe and North America fishermen catch carp with hook and line, and certain cyprinids like the minnow are used as bait.

Other cyprinids are known for their unusual methods of reproduction. The bitterling, for instance, hatches from eggs that have been deposited inside the shell of a freshwater mussel (see page 21). Perhaps the best known member of the carp family is the goldfish. These beautiful fish, which come in a number of forms, are favourite aquarium and pond fish throughout the world.

Japanese dace (*Tribolodon hakonensis*) in breeding colours. Many species show colours like this.

The red and white nishiki carp. Nishiki carp are specially bred for their beautiful appearance; they can be very expensive but the investment is a long-term one—some nishiki carp are said to live for one hundred years or more.

Japanese rose bitterlings (*Rodeus ocellatus*).

Southern top-mouthed minnow (*Pseudorasbora parva*).

Herbivorous Japanese chub (*Ishikauia steenackeri*).

The silver bighead carp (*Hypophthalmicthys molitrix*) comes from China.

This young silver carp (*Artisticthys nobilis*) is a native of China.

The striped barb (*Capoeta tetrazona*), found in Sumatra and Borneo, is a popular aquarium fish.

This shiny barb (*Barbus schwanenfeldi*) is an attractive aquarium fish and also good to eat. It is found in Southeast Asia.

This small but aggressive 'red shark' (*Labeo bicolor*) takes its name from its shape and the colour of its tail.

A male pale chub (*Zacco platypus*) in breeding colours is seen on the top, with a female below. These chubs live in Japanese rivers.

Originally from China, where it is an important food fish, the common carp (*Cyprinus carpio*) has been introduced into European and North American waters. It can survive in water with a low oxygen content and lives for up to 40 years.

Their bodies reflecting the light filtering through the water, a group of pale chubs swims lazily.

GOLDFISH

Native to East Asia, the goldfish *Carassius auratus* was first domesticated in China about 1,000 years ago. Since then it has been introduced to many parts of the world. Despite its name the goldfish is naturally greenish-brown or grey, but centuries of selective breeding have produced a variety of colours including golden, black, white and silver. The extent to which such breeding has gone can be seen as well in the rather fantastic features of certain varieties: the long, flowing tail of the veiltail, the huge, swollen head of the lionhead and the large, protruding eyes of the celestial goldfish.

A veiltail, or fringetail, goldfish.

The plain goldfish.

The black telescope-eyed goldfish.

The calico-oranda goldfish.

The celestial goldfish.

The Chinese pearl-scale goldfish.

The Chinese chakin goldfish.

The silver goldfish from China.

The peacock-tailed goldfish.

The Japanese hanabusa.

The Chinese seibungyo goldfish.

A lionhead goldfish.

LOACHES

Closely related to carp and characins, loaches *(Cobitidae)* are mostly small, slender, nocturnal fish that thrive on the bottoms of streams, lakes and swamps in Asia, Europe and Africa. They have small eyes and skin covered with very small scales. Whisker-like barbels around their mouths help them to search for food on the bottom. Certain species like the coolie and clown loach are popular aquarium fish because they are good scavengers and clean microscopic algae off aquarium plants and the glass of the tank. One loach, the weatherfish, can predict the weather: It becomes very restless when the atmospheric pressure falls before an approaching storm.

The delicate loach (*Cobitis delicata*) is found in streams.

A mud loach (*Misgurnus anguillicaudatus*), an inhabitant of the muddy bottoms of rivers and ponds.

Coolie loach (*Acanthophthalmus kuhli*), from Java and Sumatra, buries itself in mud and comes out to feed at night.

The weatherfish (*Misgurnus fossilis*) is found in Europe and western Asia.

The clown loach (*Botia macracanthus*) is found in Borneo and Sumatra.

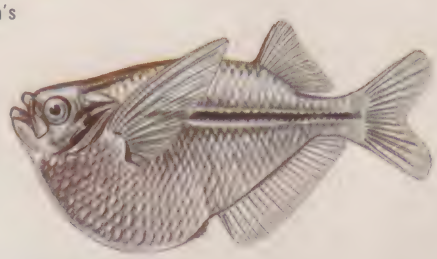
CHARACINS

The characins *(Characidae)*, found only in fresh water in South America and Africa, include such seemingly dissimilar members as the lovely little tetras, prized as aquarium fish for their brilliant colours, and the deadly piranha, feared for their ability to kill. Piranha will attack even large mammals like a horse or a man if they happen to be bleeding from any kind of wound. Attracted by the blood and armed with their razor-sharp teeth, a hungry shoal reduces the victim to a skeleton in minutes.

Other characins are known for their acrobatics. Male and female spraying characins leap out of the water to spawn on a leaf or stone, repeating the action until over one hundred eggs are laid. The male then keeps the eggs moist by using his tail to spray them periodically with water until the fry hatch and wriggle into the water. Another species, the hatchet fish, flies by beating its pectoral fins against the water to take off and glide over the surface.

The African tiger fish (*Hydrocyanus goliath*) is a savage killer like the piranha. It lives in lakes in tropical Africa.

The spraying characin (*Copeina arnoldi*) of South America's Amazon River region.



The common freshwater hatchet fish (*Gasteropelecus sternicla*), found in tropical South America, has a compressed body that tapers to a sharp edge on its underbelly.

Neon tetras (*Hyphessobrycon innesi*) are named for their brilliant colours, which glow in the water like neon lights.

Congo tetras (*Phenacogrammus interruptus*) of Africa's Zaire River are popular in aquariums. The middle rays of the tail are elongated, especially in males.

Distichodus altus, an African characin.

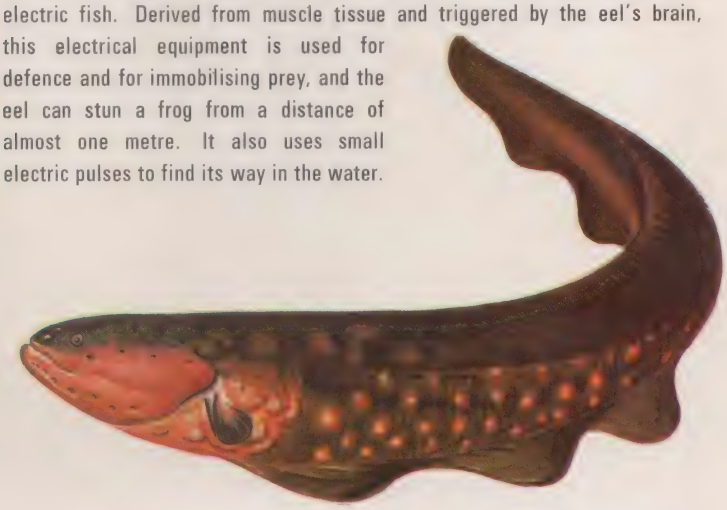
The pink-tailed characin (*Chalceus macrolepidotus*) of South America.

The flame tetra (*Hyphessobrycon flammeus*) of South America is a popular aquarium fish.

The red piranha (*Serrasalmus nattereri*) lives in large shoals in the rivers of northern South America. Although only 30 centimetres long, it is a dreaded killer.

ELECTRIC EELS

Found in fresh waters in the northern region of South America, the electric eel is a relative of the characin. It swims by ripple-like movements of its long anal fin. The animal gets its name from the powerful electric organs on its body, which can produce a shock up to 600 volts, much higher than any other electric fish. Derived from muscle tissue and triggered by the eel's brain, this electrical equipment is used for defence and for immobilising prey, and the eel can stun a frog from a distance of almost one metre. It also uses small electric pulses to find its way in the water.

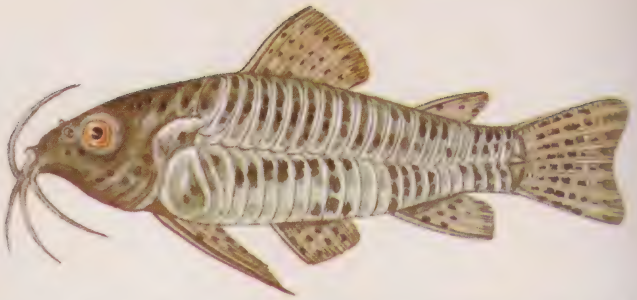


The electric eel (*Electrophorus electricus*).

CATFISH

There are more than 1,500 species of catfish *(Siluroidea)*. Most are found in tropical fresh waters, though some live in the sea. Catfish have broad heads with several long, sensitive barbels around the mouth that resemble the whiskers of a cat and give the fish their name. The barbels contain many taste buds and are used to find food in murky waters.

· Catfish are generally scaleless, but some South American armoured varieties have a covering of overlapping, bony plates. Some can be dangerous: Certain species have poisonous, saw-toothed spines, and the electric catfish can discharge a shock of up to 450 volts from an electric organ composed of modified muscle tissue just under the skin. The varied characteristics of other species include the ability to breathe air through special supplementary breathing organs, to walk on land and to make growling noises. The catfish's rich, fatty flesh makes certain varieties important food fish.



The common armoured catfish (*Calichthys calichthys*), found in South America, has two rows of bony plates along its sides and poisonous spines in the front of the dorsal, pectoral and fatty fins.

The talking catfish (*Acanthodora spinosissimus*) is an armoured catfish from tropical South America that gets its name from its ability to make growling noises.

The Southeast Asian glass catfish (*Kryptopterus bicirrhus*) is so transparent that its bones and internal organs can be seen through its skin.

Timid *Corydoras paleatus* is a small armoured catfish from South America. Its appealing look and scavenging ability make it a popular aquarium fish.

The electric catfish (*Malapterurus electricus*) of tropical Africa.

The eye-catching warning stripes of these Indo-Pacific marine catfish (*Plotosus anguillaris*) emphasise the danger of the approaching shoal. Each fish has sharp, poisonous spines in the dorsal and pectoral fins, capable of inflicting painful wounds that are slow to heal.

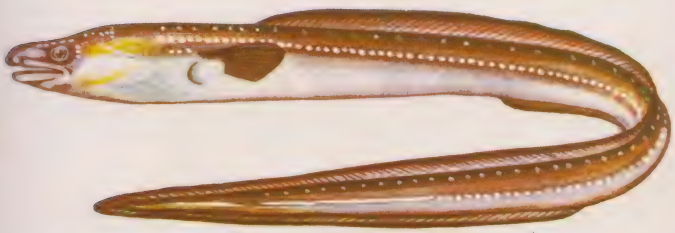
Plecostomus, a sucker-mouthed, armoured catfish from South America, is a useful scavenger in the aquarium.

EELS

Most of the more than 350 species of true eels *(Anguilliformes)* live in the sea, though some well known species inhabit fresh water. Eels have long, snake-like bodies with continuous dorsal, anal and tail fins. This allows them to live in and explore narrow crevices or underwater holes with ease.

Eels usually rest during the day and hunt for food at night. Some, like the moray and conger, are fierce predators with strong, powerful teeth and tenacious bites. Others, like the garden eel, are less aggressive feeders. Living in a burrow in the sandy sea bottom from which it extends the upper part of its body, the garden eel is content to wait patiently for something tasty to swim by. Certain species of eel are valuable food fish. Several fish unrelated to eels despite their names—electric eels, spiny eels, cusk eels and others—have evolved into an eel-like shape.

The Japanese eel (*Anguilla japonica*), found in the rivers of Japan, is closely related to European and North American eels.



This small conger eel (*Astroconger myriaster*) lives in shallow temperate waters of the North Pacific. It is only 90 centimetres long, but some larger species reach 2.5 metres.

THE MYSTERY OF THE FRESHWATER EEL

How freshwater eels breed has always been a mystery to us. We know that adult eels must go to the sea to reproduce, even if they have to migrate overland to get there, and that young eels, called *elvers,* leave the sea and return to freshwater rivers. But the eel's sex organs are not visible, and even a man as wise as the Greek philosopher Aristotle thought eels were produced spontaneously from mud. We do know quite a bit about their life cycles, however. Early in the 20th Century, a Danish scientist discovered that the European eel migrates up to 7,000 kilometres across the Atlantic Ocean to spawn in the Sargasso Sea. Although its eggs have never been seen, we now know that they hatch into transparent leaflike larvae. The larvae drift in the current of the Gulf Stream, taking more than three years to reach Europe, the place where their parents' journey began. Changing into elvers near the European shore, the animals enter the freshwater rivers and lakes where they will spend up to 18 years as adults before returning to the sea for their final journey. Similar migratory eels are found in the Pacific.

Elvers, young eels, journey upriver from the sea to freshwater homes.

A leptocephalus, the slender, leaflike larva of the freshwater eel. It is colourless, and its blood contains no red corpuscles.

An Indo-Pacific moray eel (*Gymnothorax kidako*) emerges from the hole in the coral reef it shares with a barber shrimp seen upside down above the eel. The shrimp cleans parasites off the moray's body in return for the protection it gets by living with the eel.

The beautiful pygmy moray eel (*Rhinomuraena ambonensis*) flourishes in eastern Indonesia.

Three garden eels (*Gorgasia*) poke their heads out of their sandy burrows in search of food. If disturbed, the eels withdraw completely.

Gymnothorax favagineus, a white-lined moray eel from the Indo-Pacific.

FLYING FISH AND THEIR RELATIVES

Known for their dramatic aerial performances, flying fish and their relatives *(Beloniformes)* usually inhabit tropical and temperate seas, though a very few live in fresh water. Swimming near the surface, they often leap out of the water, helped by the long, powerful lower lobe of the unevenly forked tail fin. The most spectacular aerealists of the group are the flying fish, which are able to glide through the air by spreading their large, winglike fins. In some species only the pectoral fins are enlarged and used for flying; others are four-winged, using enlarged pelvic fins as well. Needlefish are skilled jumpers, making repeated leaps through the air, often over objects floating in the water.

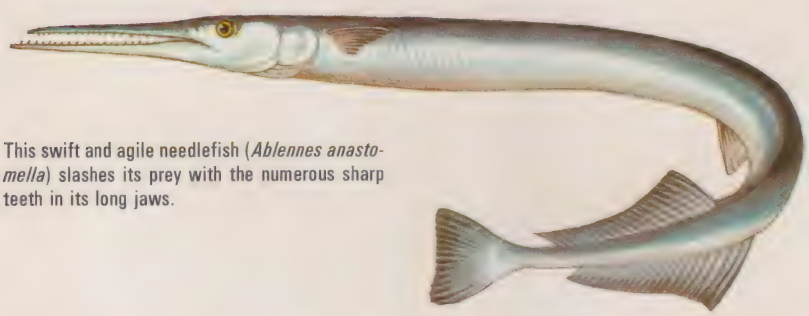
HOW FLYING FISH FLY

The flying fish does not really fly, it glides. Swimming vigourously at an angle to the surface (1), the fish begins to leave the water, gaining thrust from rapid beats of the powerful lower lobe of its tail (2). Once airborne it spreads its winglike pectoral fins to begin its glide (3). With pectoral fins fully extended it sails for 30 to 50 metres (4) before sinking back to the surface where another beat of its powerful tail propels it up into the air again. After it has performed this exercise several times the flying fish will drop headlong into the sea again.

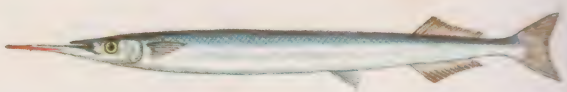
This flying fish (*Cypselurus heterurus*) lives in shoals in the open seas of the Atlantic and Pacific Oceans where it feeds on plankton with its short jaws.

The edible flying fish *Cypselurus arcticeps*.

The Pacific saury (*Cololabis saira*) is found in large shoals in the open sea. It is often canned for food.



This swift and agile needlefish (*Ablennes anastomella*) slashes its prey with the numerous sharp teeth in its long jaws.



Common in tropical coastal waters, halfbeaks (*Hemirhamphus*) have an upper jaw that is much shorter than the lower jaw. They feed by skimming food from the surface of the water into their open mouths.

Airborne over a vast blue sea, a solitary flying fish leaves a corkscrew-like wake on the surface of the water.

A shoal of halfbeaks.

TOOTHCARP

Found near the surface of fresh water in both tropical and temperate climates on most continents, toothcarp *(Cyprinodontiformes)* are very small, spindle-shaped fish with flat heads. Their name comes from the fact that, unlike true carp, toothcarp have mouths with teeth. But like their larger namesakes, they are able to project their jaws forward to snap up tiny plants and animals.

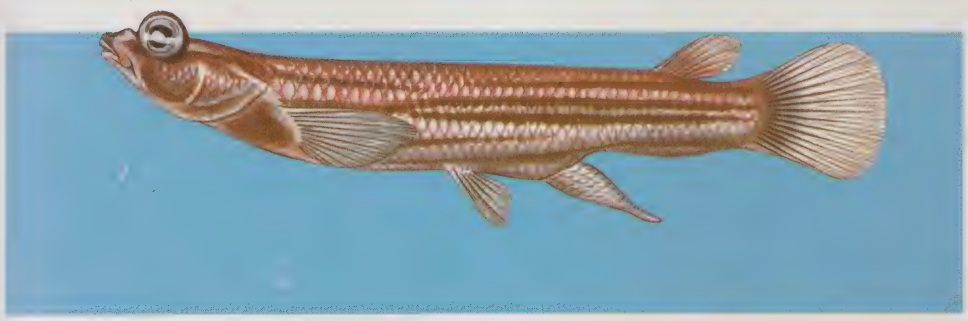
Because of their small size, bright colouring and lively behaviour, toothcarp like guppies, platies and swordtails are the most popular of all tropical aquarium fish, and selective breeding has produced many beautiful varieties. The guppy breeds rapidly, making it very useful for scientific experiments. The largest toothcarp, the four-eyed fish, is also one of the most interesting for its eyes are divided into upper and lower halves enabling it to focus on objects both above and below the water at the same time.

The aggressive green swordtail (*Xiphophorus helleri*) male of Central America has a long, tapering tail fin that looks like a bright yellow sword.

The top minnow, or mosquito fish (*Gambusia affinis*), of North America eats mosquito larvae.

The northern cavefish (*Amblyopsis spelaeus*) is a blind and colourless fish found in the limestone caves of the central United States.

This guppy (*Lebistes reticulatus*) is found in fresh water on Caribbean islands and in South America.



Largest of the toothcarp, the four-eyed fish (*Anableps tetrophthalmus*) is found in Central and South America, where it swims on the surface, its eyes half above and half below the water level.

Selective breeding has produced fancy varieties of guppies like this pair. The smaller fish is the male.

The red platy (*Xiphophorus maculatus*) is closely related to the swordtail, but it is shorter, stouter and not as aggressive.

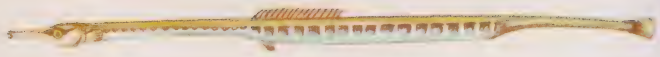
Two red swordtails (*Xiphophorus helleri*) swim in an aquarium. The female (left) has no swordlike tail.

PIPEFISH, SEAHORSES AND THEIR RELATIVES

Pipefish, seahorses, trumpetfish and sticklebacks belong to an unusual group of fish called *Gasterosteiformes,* the members of which have a wide variety of peculiar shapes. Most live in shallow tropical seas, although a few are found in fresh water. They usually have a dorsal fin with spiny rays or with two or more spines in the front of it. Some species have long, tubular mouths, which they use like a syringe to suck in their food. Many have a protective covering of bony plates over their bodies. The males of most species look after the eggs until they hatch.

PIPEFISH

Pipefish *(Syngnathidae)* have cylindrical bodies covered with bony plates and can anchor themselves by curling their long, slender tails around seaweeds. Some, like the razorfish, have greatly flattened bodies with tails bent at right angles, enabling them to swim slowly in a vertical position. Pipefish perform intricate and beautiful mating dances during which the pair intertwines and the female deposits her eggs into the male's *brood pouch,* a groove on the underside of his body covered by two flaps. The male then fertilises them and carries them about in the pouch until they hatch and the fry swim out.



This pipefish (*Syngnathus schegeli*) is found in grassy sea beds of quiet bays in Japan.

The Indo-Pacific cornet fish (*Fistularia villosa*) uses its long, tubular mouth to suck in small fish and crustaceans. After laying its eggs in the water it abandons them.

The ghost pipefish (*Solenostomus paegnius*) looks like a piece of green seaweed.

The long, thin trumpet fish (*Aulostomus maculatus*) lives in the warm coastal waters of the Atlantic Ocean, often in a vertical position with its head down, waiting for small fish on which it feeds.

Bellows fish, or snipefish (*Macrorhamphosus scolopax*), have a compressed body with spines on the back and long, toothless jaws. They can swim both forward and backward.

The razor fish, or shrimp fish (*Aeoliscus strigatus*), flourishes in the coastal waters of the Indian Ocean, often living among the spines of sea urchins. Transparent bony plates cover its body.

SEAHORSES

Of all the fish in the world, only the curious seahorses *(Hippocampus)* have heads at right angles to their bodies. Besides their horselike heads, these unique creatures are characterised by consecutive rings of body armour and long, finless tails. They usually curl their tail up under the belly for swimming or around objects in the water to anchor themselves. Seahorses swim in a vertical position by rapidly fanning their short, spiny dorsal fin. During courtship the female deposits her eggs in the male's brood pouch, a tissue-lined groove in his belly with a small opening. There they are fertilised and partially nourished from the father's bloodstream until the young are ready to leave the pouch and live independently.

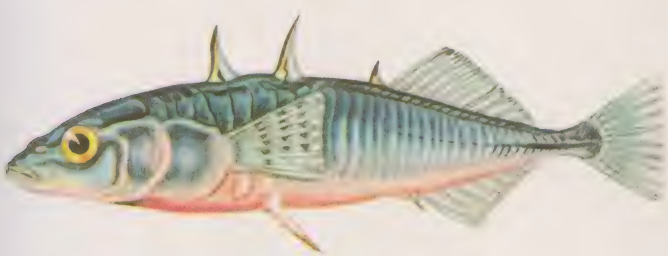
The Australian seahorse (*Phyllopteryx eques*) looks like a piece of seaweed and is thus difficult to distinguish. In place of a brood pouch, the male has spongy tissue that keeps the female's eggs attached to his body.

A bright red Indo-Pacific seahorse (*Hippocampus coronatus*) swims among seaweeds.

STICKLEBACKS

Sticklebacks *(Gasterosteidae)* are small fish found in temperate fresh, brackish or sea waters in the Northern Hemisphere. They can be recognised by the short, sharp spines sticking up from their backs in front of the dorsal fin. Each pelvic fin is usually composed of one strong, spiny ray. The body is scaleless but does have a protective covering of bony plates. Sticklebacks are known for their characteristic mating behaviour (see page 21).

The nine-spined stickleback (*Gasterosteus pungitius*) is found in cold fresh waters of the Northern Hemisphere.



This three-spined stickleback (*Gasterosteus aculeatus*) is widely distributed in the cold fresh and salt water of northern Asia, America and Europe.

This three-spined stickleback (*Gasterosteus microcephalus*) inhabits fresh waters in Japan.

CODFISH

The codfish family *(Gadiformes)* includes a number of very important food fish, most of which live near the sea bottom in the Arctic and northern temperate regions. Codfish have three dorsal fins, and their pelvic fins are near the front end of the body, under the head. Their bodies are covered with small scales, and most species have a barbel on the chin. Females can lay about four to five million eggs seasonally.

The Pacific cod (*Gadus macrocephalus*) is found in deep waters where it feeds voraciously on crustaceans, molluscs and fish.

These saffron cod (*Eleginus gracilis*) of the North Pacific are often caught in winter with a hook and line through holes cut in the ice.

SOLDIER FISH AND THEIR RELATIVES

Soldier fish, or squirrelfish, belong to an order of fish *(Beryciformes)* characterised by bodies armed with spines in the dorsal, anal and pelvic fins and covered with rough, prickly scales. The pelvic fins are placed well forward. While this group does include many deep-sea species, the red soldier fish is common on all coral reefs, hiding during the day and feeding at night.

The pine-cone fish (*Monocentrus japonicus*) of the Indo-Pacific gets its name from the thick scales that cover its body. It produces light from organs on its lower jaw.

This spiny, red soldier fish (*Ostichthys japonicus*) lives in deep waters in the temperate North Pacific.

A relative of soldier fish, the searchlight fish (*Photoblepharon palpebrata*) of eastern Indonesia has a light under each eye. The fish can turn off the lights by lowering eyelids that cover them like shutters.

DORIES AND BOARFISH

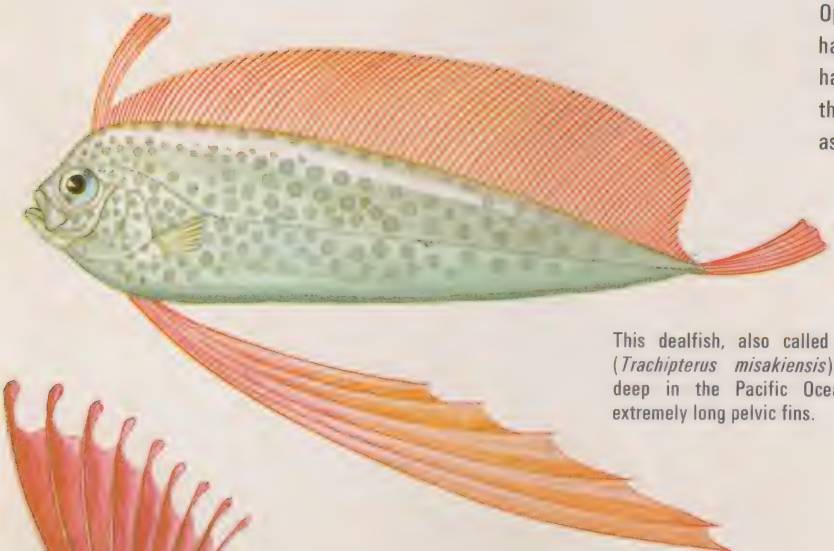
Dories and boarfish *(Zeiformes)* are found in all seas, sometimes at great depths. They have large heads with eyes placed high on the sides, spiny rays and small scales, or no scales at all. Their bodies are so thin from side to side that they can stalk their prey unnoticed, moving only the dorsal and anal fins. When close enough, they suddenly shoot their jaws forward and swallow the unfortunate victim.

A young Indo-Pacific dory (*Zeus japonicus*)

This boarfish (*Antigonia capros*) lives deep in subtropical Pacific waters.

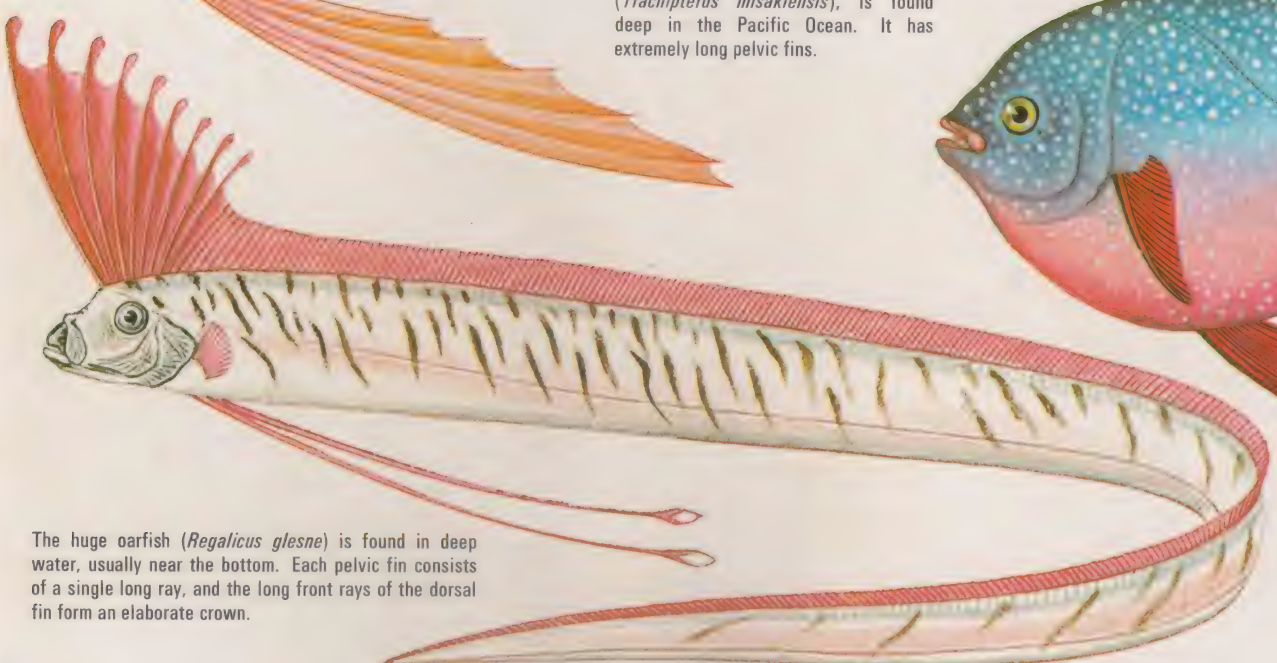
OPAHS, OARFISH AND DEALFISH

Opahs, oarfish and dealfish belong to an order of soft-rayed, marine fish *(Lampridiformes)* characterised by toothless mouths that can be thrust forward. Members of the order vary greatly in size and many have unusual shapes. Opahs are large, full-bodied fish with attractive colouring. Oarfish and dealfish have long, slender, ribbon-like bodies and are found in deep water. Both have dorsal fins that extend from head to tail, rising to a crownlike crest over the head. Growing up to 10 metres in length, oarfish are occasionally washed ashore dead and are the source of certain sea-serpent legends.



This dealfish, also called ribbon fish (*Trachipterus misakiensis*), is found deep in the Pacific Ocean. It has extremely long pelvic fins.

Found in all warm oceans, the opah, or moonfish (*Lampris regius*), can grow to two metres and weigh up to 200 kilograms.



The huge oarfish (*Regalicus glesne*) is found in deep water, usually near the bottom. Each pelvic fin consists of a single long ray, and the long front rays of the dorsal fin form an elaborate crown.

PERCH RELATIVES

Ranging extensively from shallow freshwater ponds to great ocean depths, perch and their relatives *(Perciformes)* make up the most numerous order of fish, including some 8,000 species grouped into well over a hundred families. They vary from dainty little damselfish to giant groupers and include all the fish shown from here up to page 98. Members of this group have saw-edged scales, and their fins are supported by both soft and spiny rays, the latter usually found in the front part of the dorsal, anal and pelvic fins.

The common perch (*Perca fluviatilis*), widely distributed in Europe, has a high dorsal fin and broad, vertical bars of colour across its back and sides.

SEA PERCH AND BASS

Perchlike fish in the sea not only show a variety of sizes and shapes but differ widely in their habitat and in their behaviour. Many are good food and game fish found widely in coastal waters of both tropical and temperate seas. Some, like the tiny, delicate almost-transparent glassfish and the gaily spotted scat, can tolerate brackish and fresh water and have become popular aquarium fish. Groupers change colours according to their emotional state; grunts make piglike sounds by grinding the teeth in their throats.

The thick-lipped grunt, or sweetlips (*Plectorhynchus cinctus*), from the tropical Pacific.

This sea bass (*Doderleinia berycoides*) is common in Japanese seas and grows to a length of 50 cm.

FRESHWATER PERCH AND BASS

Perch *(Percidae)* inhabit fresh water as do the beautiful bluegill sunfish and the large, fierce bass (both *Centrarchidae)*. Most species exhibit highly developed nesting habits: After the eggs are carefully laid in a depression on the bottom, they are tenaciously guarded by the male, who continues to keep watch over the young fry. One species, the North American largemouth bass, one of the smartest and gamest of freshwater fish, is a particularly ferocious predator, feeding on other fish, frogs and even young ducks. Most species are popular food and game fish.

The common bluegill sunfish (*Lepomis macrochirus*) is found flourishing in rivers and lakes of the United States.

The North American largemouth bass (*Micropterus salmoides*) is a medium-sized and fierce predaceous fish.

The short bigeye (*Pristigenis alta*) lives in the tropical West Atlantic.

The Japanese porgy (*Erynnis japonica*) has lovely, shining blue dots.

These Southeast Asian spotted scats (*Scatophagus argus*) live in brackish water. The young move upriver to live in fresh water.

These little glassfish, or glass perch (*Chanda lala*), flourish in seas around India and Burma and are popular in aquariums.

Very bright lighting was required to photograph this school of perchlike fishes (*Sacura margaritacea*) at the bottom 80 metres below the surface of the Japan Sea.

The enormous mouths of groupers like the 100-kilogram *Epinephelus malabaricus* have jaws that act like suction pumps to draw in any food lying in their path.

GOATFISH

Goatfish *(Mullidae)* are found in warm and tropical seas. While also called surmullets or red mullets, they are not related to true mullets (see page 95). Goatfish have long bodies covered with large scales, eyes high on their heads and small mouths. Beneath their chins are two long barbels—used as feelers for detecting food on the sea bottom—that can be flattened into a groove on the throat when they are not in use. Goatfish are often brightly coloured in shades of red and yellow; some have the ability to change their colours. Many species are valued as food.

A red goatfish (*Upeneus bensasi*) that is found from the Indian Ocean to Japan.

Yellow goatfish (*Parupeneus cyclostomus*) swim on a coral reef in the Indian Ocean. The large fish in the centre is a male; the rest are females.

CARANGIDS

Carangids *(Carangidae)*, which include the jacks, pompanos and horse mackerel, are a family of swift, good food and game fish found throughout the world in warm, shallow seas. Members of the family show a variety of shapes, with some thin and disc-shaped and others with long, torpedo-like forms. Many have hard scales called *scutes* along the lateral line. The young of certain carangid species take shelter among the tentacles of jellyfish or under floating seaweeds. A more risky kind of protection is sought by the pilotfish: Swimming by the heads of sharks but carefully avoiding their mouths, the pilotfish gains a bodyguard and the shark's leftovers.

A shoal of carangid fish.

The pilotfish (*Naucrates ductor*) is found throughout the tropical seas of the Indo-Pacific region.

The sleek pompano (*Trachinotus carolinas*) is a fast swimmer in coastal waters of the West Atlantic.

The threadfin jack (*Alectis indica*) has long, threadlike fin rays which are thought to stabilise the fish, though they tend to break off in later life. It is found in tropical waters.

The great trevally (*Caranx sexfasciatus*) is found throughout the Indo-Pacific region.

The slipmouth, or pony fish (*Leiognathus nuchalis*), left, is found in Japanese waters. To feed, it suddenly extends its jaws and sucks in its food (right).

A shoal of Pacific butterfish (*Labracoglossa argentiventris*).

Found along the Atlantic coast of North and South America, the lookdown (*Selene volmer*) is characterised by a very high forehead.

DOLPHIN FISH

Relatives of carangids found in tropical waters around the world, dolphin fish *(Coryphaenidae)* have large heads, tapered bodies and deeply forked tails. They are great leapers and swift swimmers, capable of reaching speeds of up to 60 kilometres per hour when chasing their favourite prey, flying fish. Growing to 2 metres in length, dolphin fish are a good food source. They are noted for the changes in their brilliant blue and gold colouring as they die.

The dolphin fish (*Coryphaena hippurus*).

CICHLIDS

Cichlids *(Cichlidae)* are freshwater fish found in Central and South America, Africa and India. While the nostrils of most fish consist of U-shaped tubes with two openings on each side of the head, cichlid nostrils have only a single opening. Cichlids are noted for their complex mating and breeding behaviour, and different species exhibit different ways of caring for their eggs and young. Some lay their eggs on a carefully cleaned stone and fan the eggs to aerate them; others lay them in a pit on the bottom. After they hatch one of the parents may guard the young by taking them into its mouth. In some species the female picks up the eggs in her mouth and fertilisation takes place there. The eggs are then protected in her mouth until they hatch and are old enough to swim outside. Parents of young discus fish take turns at feeding their young in a rather unusual manner: They let their offspring (fry) attach themselves to the skin of the parent and feed on a special mucous secretion. Many cichlids are popular aquarium fish.

These tilapia (*Tilapia mossambica*) are African mouthbreeding fish that have been introduced and cultivated elsewhere for food.

The jewel fish (*Hemichromis bimaculatus*) is so aggressive that weaker ones are killed during the breeding season.

These freshwater angelfish (*Pterophyllum einmekei*), which come from South America, are popular aquarium fish.

The discus (*Symphysodon discus*) flourishes in the Amazon basin. The discus is difficult to breed and is expensive.

Kribensis fish (*Pelmatochromis pulcher*) are small African cichlids. The male (left) has two eyespots on its tail.

The red oscar (*Astronotus ocellatus rubra*) from South America is a popular aquarium fish, although it is aggressive and difficult to breed.

The banded cichlid (*Ciclasoma severum*) is a timid fish that is difficult to breed in an aquarium.

BUTTERFLYFISH

Butterflyfish *(Chaetodontidae)* are thin, deep-bodied fish with an almost circular outline found on coral reefs around the world. Their brilliant colouring includes bold patches and bands that serve to break up their characteristic shape and thus help to camouflage them. With the real eyes hidden in black bands and in many species a black eyespot showing prominently in front of the tail, butterflyfish further confuse predators into thinking they are back to front. Butterflyfish are additionally protected by a row of spines on the back that make them a very unpleasant mouthful. Some butterflyfish have flattened, chisel-like teeth to pick off coral polyps, while others have tiny protruding teeth at the tip of their pointed snouts to remove food from crevices.

The butterflyfish *Chaetodon collaris*.

The "poor man's Moorish idol" (*Heniochus acuminatus*) is a butterflyfish, but gets its name because it resembles the Moorish idol (see page 92). The two fish are not related, however.

This butterflyfish (*Chaetodon lunula*) is widely distributed on coral reefs of the Indian and Pacific Oceans.

The butterflyfish *Chaetodon modestus*.

The butterflyfish *Chaetodon plebeius*.

The stripey (*Microcanthus strigatus*) lives in coral areas in the South Pacific.

The threadfin butterflyfish (*Chaetodon auriga*), from the Indian and Pacific Oceans.

A long-nosed butterflyfish (*Chelmon rostratus*).

Bennett's butterflyfish (*Chaetodon bennetti*) is found all over the coral reefs of the Indo-Pacific.

The eyespot near the tail of this long-snouted butterflyfish (*Forcipiger flavissimus*) from the Indo-Pacific makes it very difficult to distinguish where the animal's head really is.

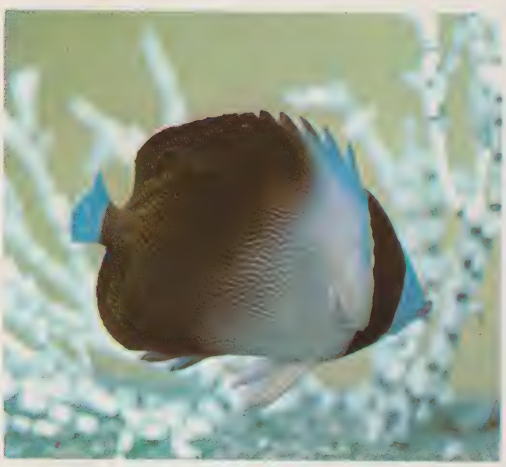
MARINE ANGELFISH

Marine angelfish *(Pomacanthidae)* look like larger editions of the brightly coloured butterflyfish, with which they share the coral reefs. Flat, deep-bodied fish, they are distinguished from butterflyfish by a spine at the base of each gill cover. Except during mating, angelfish live a solitary existence, and each fish vigourously defends its own territory. When another member of the same species intrudes, it will engage in a threatening display, showing off its colours. If the invader does not move away, there will be a fight.

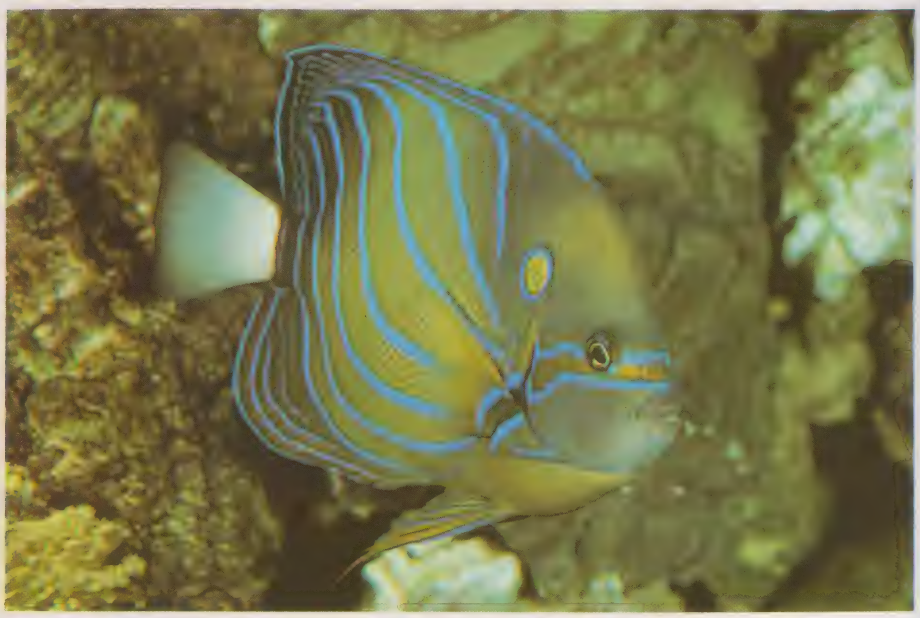
Emperor angelfish (*Pomacanthus imperator*)

Two angelfish on a coral reef—the zebra angelfish (*Pygoplites diacanthus*) above and the yellow angelfish (*Holacanthus trimaculatus*) below.

Two young angelfish—the Koran angel (*Pomacanthus semicirculatus*), left and the emperor angel (*Pomacanthus imperator*), right. Though often resembling each other when young, angelfish species look quite different when matured.



The vermiculated angelfish (*Chaetodontoplus mesoleucus*) has a thick, black band camouflaging its eye.



The blue-ringed angelfish (*Pomacanthus annularis*) is found on coral reefs in the Indo-Pacific region.

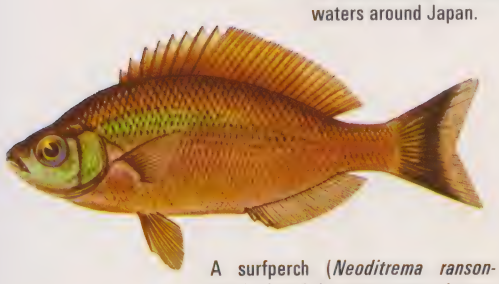
This blue-and-gold angelfish (*Centropyge bicolor*) is found near Indo-Pacific coral reefs.

The yellow-faced angel (*Euxiphipops xanthometopon*) is found on coral reefs of the Indian and Pacific Oceans.

SURFPERCH

Surfperch *(Embiotocidae)* are small- or medium-sized shore fish that are accustomed to the surf. Most are confined to American coastal waters from California to Alaska, though two species are found around Japan. One species is unusual among marine fish in giving birth to live young instead of laying eggs. Even more unusual is their ability to mate soon after birth. The female stores the sperm in her body for several months, ready to fertilise her eggs when they are produced. The eggs have very little yolk, so the baby developing inside the mother must receive food and oxygen from her body.

This surfperch (*Ditrema temmincki*) is found among seaweeds in shallow waters around Japan.



A surfperch (*Neoditrema ransonneti*), found in warm coastal seas of the North Pacific.

Batfish like this Indo-Pacific *Platax* are often seen drifting lazily in the warm waters above coral reefs.

Batfish (*Platax pinnatus*) are widely distributed in warm ocean waters. They are flat, resembling a table tennis bat, and sometimes swim on their sides.

ARCHER FISH

Archer fish *(Toxotes jaculator)*, which live in fresh and brackish waters in India, Southeast Asia and Australia, have a unique method of hunting. They swim around busily at the surface, looking for insects on low branches of bushes. When a prey is sighted, the fish directs an amazingly accurate jet of water at it, causing the insect to fall onto the water surface, where it is eaten. The water jet is produced by forcibly closing the gill covers while the tongue acts like a piston in forcing water along a groove in the roof of the mouth. Archer fish can hit a target up to one metre above the water.

The archer fish (*Toxotes jaculator*).

Floating in the waters of the Amazon Basin, leaf fish (*Monocirrhus polyacanthus*) look exactly like dead leaves. They can change colour to match their surroundings, enabling them to sneak up on prey unnoticed. With their greatly extendable mouths these South American leaf fish can swallow fish that are half their own length.

DAMSELFISH AND THEIR RELATIVES

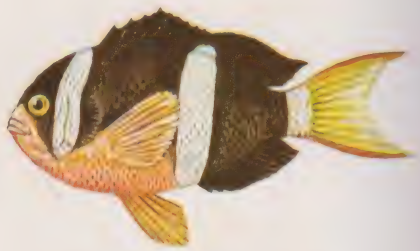
The colourful damselfish *(Pomacentridae)* are found mainly along coral reefs. Like cichlids, which they resemble, their nostrils have only one opening, and they have two spiny fin rays in the front part of the anal fin. Damselfish usually lay eggs in rock crevices and guard them fiercely. One group of damselfish, the anemone fish, or clownfish, lives among the tentacles of certain sea anemones. A special mucous skin secretion protects them from the anemone's sting cells. Damselfish are popular saltwater aquarium fishes.

The blue damselfish (*Pomacentrus coelestis*) seeks refuge near staghorn corals on Indo-Pacific reefs.

The bridled clownfish (*Amphiprion frenatus*) is found in the waters of the Indo-Pacific region.

Three brightly striped anemone fish (*Amphiprion percula*) found in tropical coastal waters of the Indian and Pacific Oceans.

The sergeant-major (*Abudefduf vaigiensis* and related species) are probably the most common of all coral-reef fish. They have vertical stripes but are not brightly coloured.



This clownfish (*Amphiprion clarkii*) is found in the western Pacific Ocean and in the Indian Ocean.

This damselfish (*Dascyllus aruanus*) flourishes on the coral reefs of the West Pacific.

A shoal of bright blue damselfish (*Chrysiptera hollisi*), popular in marine aquariums.

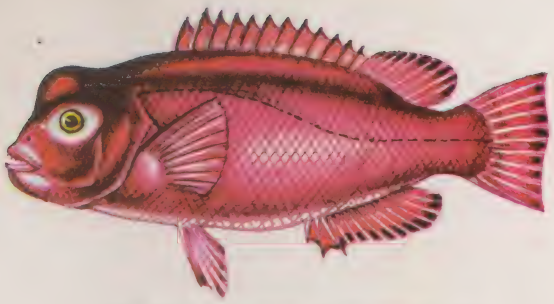
A group of chromis (*Chromis coeruleus*), damselfish seen in the Indian and Pacific Oceans.

Three three-spot damselfish (*Dascyllus trimaculatus*) on an Indo-Pacific coral reef. The small, black fish get their names from three white spots—one on the forehead and one on each side of the body—that disappear as the fishes grow older.

This beautiful fish, the fairy basslet, or royal gramma (*Gramma loreta*), inhabits Caribbean reefs. Though not a damselfish, its brilliant colours match those of even the most spectacular damselfish.

WRASSES

Wrasses *(Labridae)* are small, colourful fish found in shallow rocky seas and on coral reefs. Using a mouth that can be thrust forward, thick lips and strong, sharp teeth, they feed on snails, molluscs, worms, crustaceans and fish and can bite hard food off rocks. The little cleaner wrasse, a living vacuum cleaner, also uses this impressive mouth equipment to perform an important function for larger fish: It cleans their skin and gills by eating skin parasites, cleaning up infected tissue and removing food particles. At mating time some male wrasses prepare a nesting area and lure the female to lay her eggs there. Females of other species lay eggs in rock crevices. Then both parents cover the eggs with seaweeds and the male usually keeps guard. Wrasses sleep lying on their sides or burrow under the sand to sleep undisturbed.



This bright red wrasse (*Semicossyphus reticulatus*) flourishes in the West Pacific.

A wrasse (*Thalassoma cupido*) found in the West Pacific south of Japan.

Male

Female

The Japanese wrasse *Halichoeres poecilopteus*. The male is green in colour, and the female is red.

Two wrasses on a Malaysian reef with staghorn corals. The bird-mouth wrasse (*Gomphosus varius*), above centre, can probe into crevices. The larger blue wrasse (*Thalassoma lunare*), below right, swims solely by flapping its pectoral fins, keeping the unused tail fin folded.

This beautiful clown wrasse (*Coris gaimardi*) lives on Indo-Pacific coral reefs.

PARROTFISH

Close relatives of the wrasses, parrotfish *(Scaridae)* are often endowed with brilliant colours and have teeth in each jaw that are fused together to form a parrot-like beak. With this beak they can bite off tough seaweeds, lumps of coral or even spiny sea urchins, which are then ground up by the mill-like teeth that line their throats. Finally a fine cloud of crushed, gritty material is spat out, and the soft tissues in the food are swallowed. Some parrotfish produce a sleeping bag of hardened mucus every evening. The mucus is poisonous, ensuring the parrotfish a good night's rest.

Clearly visible in this photograph is the beak-like mouth of this parrotfish (*Scarus bowersi*).

A shoal of young parrotfish swim near corals from which they obtain their food.

ANTARCTIC FISH

Two fish found in the forbidding cold of the antarctic region are the icefish *(Chaenichthyidae)* and the Antarctic cod *(Nototheniidae)*. Both are mostly bottom dwellers. Icefish have large heads and long, projecting snouts. Their blood is colourless due to the absence of red corpuscles. Despite the name, Antarctic cod are not true codfish.

The icefish *Chaenocephalus aceratus*, top, and the Antarctic cod *Trematomus bernacchi*.

SURGEONFISH

The surgeonfish, or tangs *(Acanthuridae)*, are named for the weapons they carry: two sharp, knifelike spines, one on each side of the tail. Evolved from a scale, the spines may be snapped open like the blade of a jackknife at any sign of danger; then folded back against the fish's body when trouble is past. The spines can make deep cuts. Surgeonfish feed on algae on the reefs.

WEEVERS AND STARGAZERS

Though not directly related, weevers *(Trachinidae)* and stargazers *(Uranoscopidae)* have much in common. Both are elongated fish with large, slanting mouths; both habitually bury themselves in the sand. And each of the two groups has eyes on or near the top of the head with the stargazer named for the fact that its eyes seem to gaze up at the sky. Both, too, possess very effective methods of defence. Among the most dangerous of all the bony fish, weevers have venomous spines on each gill cover and on the first dorsal fin that can produce extremely painful wounds; certain species of stargazers have organs behind the eyes that produce electric shocks.

A stargazer (*Uranoscopus japonicus*) found in inshore waters of the North Pacific.

The greater weever (*Trachinus draco*) is found in the shallow waters of the eastern Atlantic and the Mediterranean. It lies half buried in the sea bed by day but swims about in schools at night.

The regal tang (*Paracanthurus theutis*) has been called "the bluest blue in the world."

The dusky sailfin tang (*Zebrasoma xanthurus*) of the Indo-Pacific.

Ring-tailed surgeonfish (*Acanthurus xanthopterus*).

The surgeonfish surprises predators by locking into position the white, knifelike spines located just in front and on each side of its tail-fin.

Related to surgeonfish, the Moorish idol (*Zanclus cornutus*) dwells on Indo-Pacific reefs.

MACKEREL

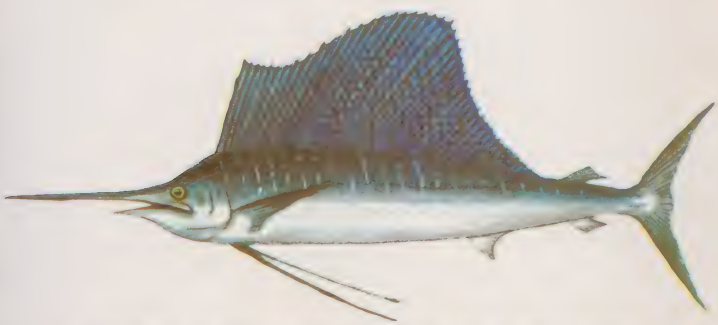
The world's fastest swimmers, members of the mackerel family *(Scombridae)* are built for speed. Their streamlined bodies are composed almost entirely of muscles which move the stiff, crescent-shaped tail fin to thrust them forward. Many species fold certain fins into grooves while swimming, lowering still further their resistance to the water. It is thought that the series of finlets in front of the tail also helps to lower resistance by reducing water turbulence. Tuna (tunnies) have been clocked at 70 kilometres per hour, about 10 times the speed of most fish. The giant of the group is the bluefin tuna, which can reach about four metres in length and weigh more than 700 kilograms. Roaming the world's great oceans close to the surface in huge shoals of about a thousand fish, bluefin tuna are so active that their body temperature may be 15 degrees centigrade warmer than the temperature of the water.

The Pacific mackerel (*Scomber tapeinocephalus*).

Bluefin tuna (*Thunnus thynnus*) are strong swimmers and voracious feeders which roam the oceans.

MARLINS AND SAILFISH

Marlins, or spearfish *(Makairidae),* and sailfish *(Istiophoridae)* resemble mackerel but have long, pointed bills which are rounded in cross-section. Sailfish carry a prominent sail-like dorsal fin. These fish have wonderfully streamlined bodies and are among the fastest swimmers. They prey on shoals of other fish, slashing at them with their bills. All are large, with the black marlin reaching over 4 metres in length and 700 kilograms in weight.



Because of its dramatic leaps when hooked and its beauty when mounted, the sailfish (*Istiophorus platypterus*) is a highly prized game fish. It is found in all tropical seas.

The blue marlin (*Makaira mazora*).

SWORDFISH

The swordfish family *(Xiphiidae)* is made up of just one species *(Xiphias gladius)* resembling the marlins and sailfish except for a tall, sharklike dorsal fin and a longer but flatter swordlike bill which extends as a bony projection of the upper jaw. Although often seen basking at the surface of both tropical and temperate seas, swordfish feed at depths of over 300 metres, chasing after squid and fish. They are good game fish, and there are many tales of attacks on boats. As proof of this, in museums there are pieces of boat planking with the swords deeply imbedded in the wood.

The swordfish (*Xiphias gladius*).

RABBITFISH

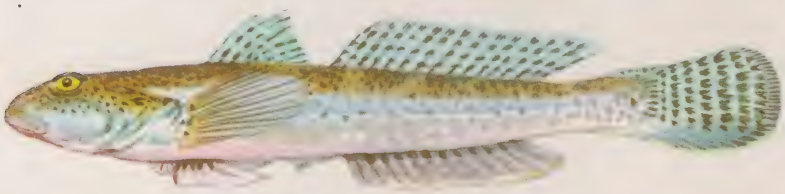
Rabbitfish, or spinefish *(Siganidae),* are medium-sized fish found in rocky areas and around coral reefs in shallow tropical waters of the Indo-Pacific from the Red Sea to Tahiti. Most are olive or brown in colour but certain species can be much brighter. Rabbitfish resemble surgeonfish, but are characterised by venomous spines on the dorsal and anal fins that can produce painful wounds. They use their small, rabbit-like mouths to nibble algae.

The black bands and spots on these coral rabbitfish (*Lo vulpinus*) of the Indo-Pacific demonstrate how disruptive colouring can break up the familiar shape of a fish.

The spotted-line rabbitfish (*Siganus javus*).

GOBIES

Gobies *(Gobiidae)* are bottom dwellers found in both fresh and salt water throughout the world, especially in the tropics. They have two dorsal fins. The pelvic fins of gobies are closely placed and often fused together to form a suction cup by which the fish attach themselves to flat surfaces. Many gobies live in burrows in sand or mud, some sharing such homes with other animals.



The goby *Acanthogobius flavimanus* is very common on shallow, muddy sea bottoms.

A sleeper (*Amblyeleotris japonica*) stands guard at the entrance to the burrow it shares with the prawn seen here busily working.

Unlike most gobies, the small, free-swimming marine gobies (*Pterogobius elapoides*) here do not live on the bottom.

This sleeper (*Eleotris oxycephala*) lies buried in the mud of rivers by day, coming out to hunt for small animals at night.

The common freshwater goby (*Gobius similis*) found in Japanese rivers and lakes.

MUDSKIPPERS

Apart from lungfish, mudskippers *(Periophthalmidae)* and some species of blennies are the only fish that spend much of their lives out of water. This is possible because their gills and gill slits are specially modified for breathing air. To bear their own weight on land, mudskippers have evolved thick, jointed pectoral fins, which they use like crutches to walk. Some can climb trees with these pectoral fins, using a sucker to hang on. Male mudskippers scoop out burrows with their mouths, spitting out mud to form the burrow's crater-like lip. Mudskippers leave their burrows to hunt on the mud flats at low tide, darting about by suddenly straightening their bent tails.

The pectoral fin of this mudskipper (*Periopthalmus koelreuteri*) looks and functions like a leg, enabling the fish to walk.

The great mudskipper (*Periopthalmodon schlosseri*) peers out at the world over the edge of its burrow.

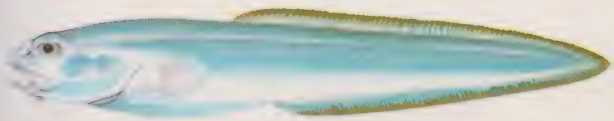
A band of tree-climbing mudskippers (*Periophthalmus chrysospilos*), found on Southeast Asian shores, rests on a sapling at high tide.

BROTULIDS AND CUSK EELS

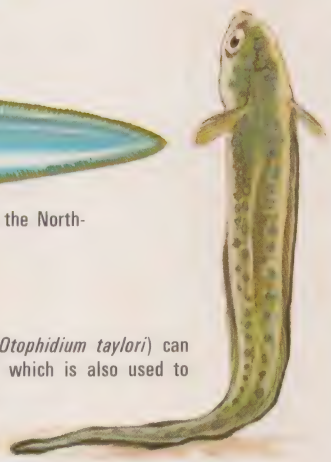
Despite their appearance, brotulids *(Brotulidae)* and cusk eels *(Ophidiidae)* are not related to true eels. Both have elongated bodies with pointed tails, and cusk eels have a single, continuous fin composed of the dorsal, tail and anal fins. Brotulids have no pelvic fins, and their skin is covered with small scales or lacks scales entirely. Most species live in the deep seas, and some are blind. Blind brotulids are also found in freshwater caves in the Caribbean. Cusk eels live on the bottom, mostly in deep water. Their pelvic fins have been reduced to a pair of threadlike rays, used to search for food.

The barbelled brotulid (*Brotula multibarbata*) is found in the waters of the Indo-Pacific region.

The brotulid *Neobythites nigromaculatus*.



This cusk eel (*Otophidium asiro*) dwells in the North-west Pacific region.



The spotted cusk eel (*Otophidium taylori*) can rest upright on its tail, which is also used to dig holes in the sea bed.

BARRACUDA

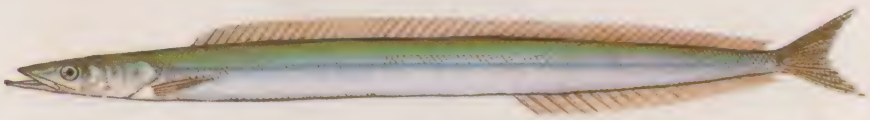
Barracuda *(Sphyraenidae)* are ferocious fish with sharp, dagger-like teeth. They often travel in shoals and attack suddenly, approaching unseen to slash their prey in two before circling back to feed. Growing up to two metres in length and weighing as much as 45 kilograms, large barracuda are even more feared than sharks in certain areas of the world; there is no clear evidence, however, that they attack people.

A shoal of barracuda (*Sphyraena japonica*) swims near the surface.

SAND LAUNCES

Sand launces, or sand eels *(Ammodytidae)*, live in cold and temperate seas where they spend much of their time buried in the sand, digging for the crustaceans and worms on which they feed; they also feed on fish fry. These fish are characterised by long, pointed heads, forked tails and small scales or no scales at all. They have slim, elongated bodies and soft-rayed fins, with the long dorsal fin set in a groove. The pelvic fins are usually absent. Sand launces are an important food source for other fish and are thus good as bait.

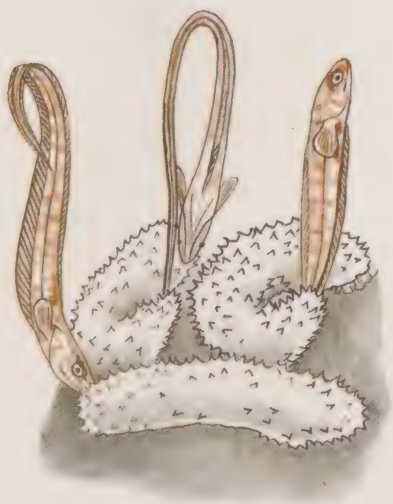
This sand launce (*Ammodytes personatus*) lives on the sandy bottoms of Japanese coastal waters.



This greater sand eel (*Ammodytes lanceolatus*) flourishes along the coasts of the eastern Atlantic. A transparent fish, it lies buried in the sand by day and at night hunts in shoals for fish fry and small crustaceans.

PEARL FISH

Related to brotulids and cusk eels, pearl fish *(Carapidae)* are scaleless, tropical animals that have no tail or pelvic fins. Small, slender and transparent, they live in the bodies of sea cucumbers and bivalve molluscs to gain protective shelter, leaving the host to forage for small organisms. In some cases they engage in parasitic feeding. Pearl fish get their name from the fact that they sometimes die inside oysters and form the nuclei of pearls.



A Mediterranean pearl fish (*Carapus acus*) enters the body of a sea cucumber. First it finds the anal or posterior opening (left), then doubles back and wriggles in tail first (centre and right).

MULLETS

Mullets *(Mugilidae)* are silvery fish with stocky bodies and two distinct dorsal fins, the first containing four stiff spines. They live in shoals in salt and brackish water, often grubbing about on the sand or mud for their food. Many have very long, coiled intestines needed for digesting their largely vegetarian diet. Mullets, found in warm and temperate seas, are valuable food fish.

The striped mullet (*Mugil cephalus*) is common in tropical seas around the world, swimming in large shoals.

LABYRINTH FISH

Labyrinth fish *(Anabantidae),* are small, tropical freshwater fish found in Asia and Africa. Though they breathe with gills like other fish, they get their name from a supplementary breathing organ called a labyrinth located above the gills. The labyrinth enables the fish to live in water containing little oxygen and, in some cases, to live temporarily out of water. The bodies of labyrinth fish are covered with saw-edged scales. The pelvic fins are under the pectoral fins, and in certain species of these versatile fish have long, threadlike rays that are used like antennae for feeling.

The males of most labyrinth species build frothy nests made of bubbles that float on the surface. After mating the male picks up the fertilised eggs in his mouth and spits them into the nest. He then stands guard over the eggs until they hatch into fry.

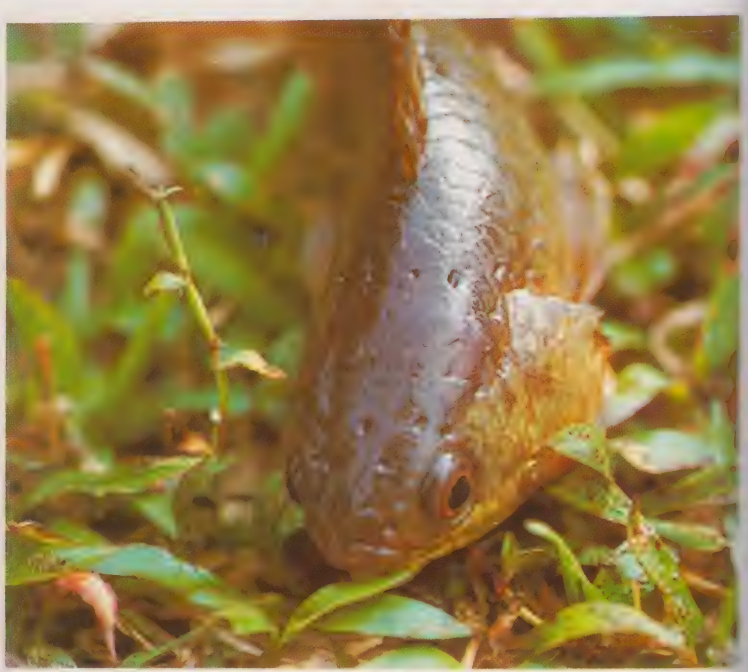
Many labyrinth fish are popular in home aquariums. The spectacular Siamese fighting fish has been specially bred to produce fighting males in a variety of colours. Fish fighting is a popular sport in some Asian countries.

Kissing gouramis (*Helostoma temmincki*) from Southeast Asia. These fish have the habit of coming together mouth to mouth, thus giving an impression of kissing. In actuality the action is probably intended to be threatening.

A pair of dwarf gouramis (*Colisa lalia*) swims through a maze of underwater growth. The male of this species is usually harmless to fish of other species, but he may kill the female after mating.

This young giant gourami (*Osphronemus goramy*) of Southeast Asia is beginning to develop a bulging forehead, which will become more pronounced as it matures. The giant gourami is a valuable food fish.

Siamese fighting fish (*Betta splendens*) courting. The male displays himself by erecting his fins and spreading his gill covers, as the female adopts a submissive posture with her head pointing downward—a position she must take in order to avoid being attacked by the male.



The climbing perch, or walking fish (*Anabas testudineus*), is known for its ability to emerge from the water and "walk" on land by using its tail and the spines on the lower edges of its outstretched gill covers.

BLENNIES

Blennies *(Blenniidae)* are a large group of small, bottom-dwelling fish. Widely distributed, they have slim bodies that, depending on the species, range from slightly elongated to very long and eel-like. All blennies have long dorsal fins, and most have pelvic fins placed near the throat. Many blennies can survive out of water for some time; some are adapted to live out of water most of the time, hanging on to rocks by a sucker on the lower lip.

A small blenny (*Tripterygion etheostoma*) from the shores of the Northwest Pacific.

This blenny (*Istiblennius enosimae*) lives in Japanese rock pools.

The blenny *Omobranchus elegans*, found in very shallow water of the Northwest Pacific.

GURNARDS AND FLYING GURNARDS

Gurnards, or sea robins *(Triglidae)*, live on the sandy bottom of shallow tropical and temperate seas. Bony ridges on their large heads, bony spines on their cheeks and strong scales on their bodies give them good protection, as if they were wearing a kind of armour. Several of the front rays of their large pectoral fins are not attached to one another and are used for walking on the sea bed and as feelers for finding food. Gurnards can make growling noises by vibrating the muscles attached to their swim bladders.

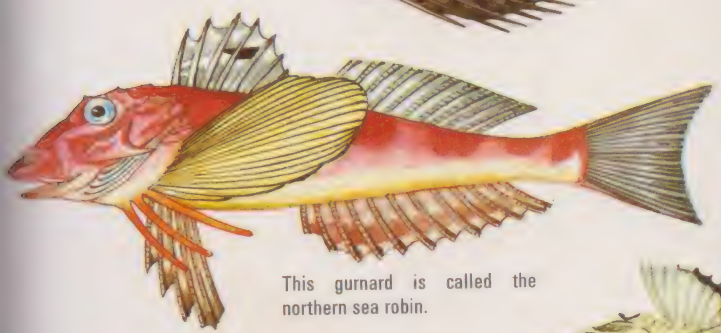
Though not closely related, flying gurnards *(Dactylopteridae)* resemble gurnards but have much larger pectoral fins shaped like wings. Often very colourful, these fins are used to walk along the bottom and, it is said, to enable the fish to glide for short distances above the water, although such information is unsupported by factual evidence. Flying gurnards are further characterised by a dorsal fin ray, separated from the rest of the fin on the nape of the neck.

DRAGONETS

Dragonets *(Callionymidae)* are bottom-dwelling fish with long, scaleless bodies and flattened, almost triangular heads. They have a jagged spine on each gill cover. The male is usually brightly coloured and has tall dorsal fins.

A brightly coloured dragonet (*Synchiropus altivelis*) from the warm seas of the Western Pacific.

A flying gurnard.



This gurnard is called the northern sea robin.

While the alligator fish, or poacher (*Podothecus sachi*), takes its name from the shape of its jaws, it is also noted for its remarkably large fins. A bottom dweller with a body covered with armour-like plates, it is found in the Western Pacific.

SNAILFISH AND LUMPFISH

Snailfish and lumpfish *(Cyclopteridae)* live in cold, northern waters and are characterised by a strong sucking disc on the underside of the body formed from the pelvic fins and used to hold the fish firmly to the sea bottom. Despite their close relationship, however, the two fish look quite different. Snailfish, also called sea snails, are elongated, tadpole-shaped fish with very long dorsal fins. Lumpfish are thick-set fish with bodies often studded with bony lumps.

This snailfish (*Liparis tessellatus*) flourishes in shallow waters of the Western Pacific.

A Japanese lumpfish (*Eumicrotremus asperrimus*), found in shallow seas.

SCULPINS

Sculpins *(Cottidae)* are small, elongated bottom dwellers found in both fresh and salt water, mainly in northern areas of the world. They have spiny heads and large, fanlike pectoral fins. Some sculpins have fleshy tabs on their heads; others can inflate their oral cavity and gill region with air when out of the water. The grunt sculpin is heavier than water and can walk on its pelvic fins.

The freshwater Japanese sculpin (*Cottus pollux*).

A grunt sculpin (*Rhamphocottus richardsoni*).

SCORPION FISH

Scorpion fish *(Scorpaenidae)* are sluggish animals that live on the sea bottom, usually among rocks or corals. Some, like the beautiful lionfish, are brightly coloured, but many exhibit dull shades providing such effective camouflage that it is nearly impossible to distinguish them from the surrounding rocks and seaweeds on the bottom. Scorpion fish have large, spiny heads and strong spines in their fins—venomous in certain species—that are capable of producing painful wounds. Most dangerous are the ugly stonefish. Lying motionless and blending almost completely with their surroundings, stonefish are difficult to see and can, when stepped on or handled, inject venom through grooves in their dorsal, anal and pelvic fin spines that produces intense pain.

Two rockfish—*Sebastiscus albofasciatus*, above, and *Sebastes inermis*, below. Rockfish are usually found along rocky shores in shallow water, but some live at great depths.

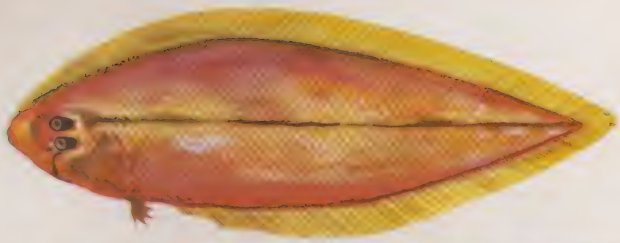
Easy to mistake for mere rocks, two deadly Indo-Pacific stonefish (*Synanceja horrida*) rest on a shallow reef.

This scorpion fish is found in African seas. Its colouring and the little skin tags that cover its body make it difficult to distinguish from its rocky surroundings.

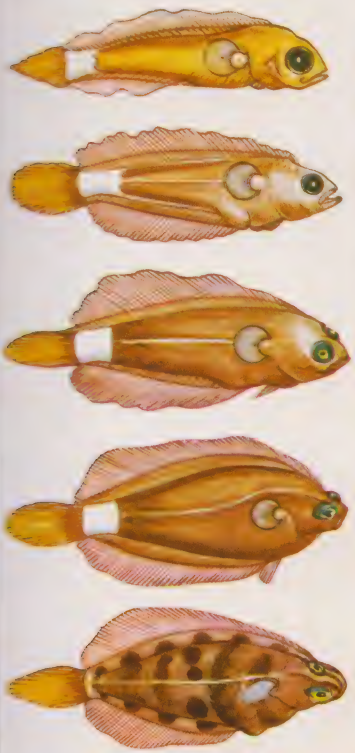
The beautiful Indo-Pacific lionfish (*Pterois volitans*) takes its name from the separated rays of its dorsal, pectoral and pelvic fins, which stand up like a lion's mane. But beauty can be deceptive, for the lionfish's spiny dorsal-fin rays are venomous and capable of inflicting very painful wounds.

FLATFISH

Flatfish *(Pleuronectidae)* are found on sandy bottoms of shallow seas, where they feed on small animals. They are well adapted to life on the sea bed because their bodies are indeed flat, as their name implies. The eyes are on the upper side of the body, which is coloured to match the surroundings; the underside is white. Flatfish are usually covered with fine scales and have a single dorsal fin beginning at the head and reaching almost to the tail fin. They are important food fish in temperate regions.

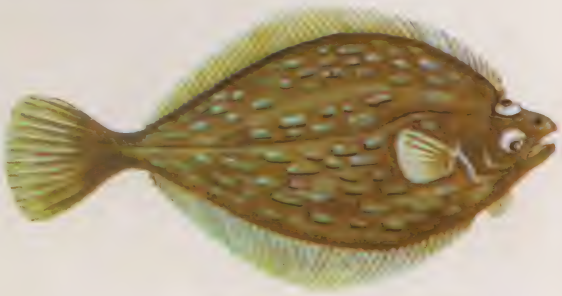


The tongue fish (*Areliscus joyneri*) is found on shallow sandy bottoms of the West Pacific. The dorsal, anal and tail fins are continuous.



Flatfish fry are born shaped like most other fish, but as they grow the eye on one side of the body moves to the other side, and they develop distinct upper and lower sides.

This flounder (*Limanda herzensteini*) is found in Japanese coastal waters.



The rough-scale sole (*Clidoderma asperrimum*) inhabits deep seas.

The colour and appearance of these flatfish match those of their surroundings.

Flatfish resting on the sea bottom, their eyes looking upward in search of prey.

PUFFERFISH

Pufferfish *(Tetraodontidae)* are slow swimmers with short, thick bodies. They have small, hairlike spines and skin so tough that it has actually been used to make helmets. When threatened, pufferfish can puff themselves up into a prickly ball by gulping in water or air; they then float upside down. Blown up in this way they are almost impossible for a predator to swallow. In both the upper and lower jaws, the puffer's teeth are fused together, giving the fish a pair of sharp-edged plates that allow it to bite off hard objects like coral. Most are tropical sea fish, but a few are found in fresh water.

In Japan pufferfish are considered a delicacy despite the fact that in many species the internal organs contain a deadly nerve poison. By law only licensed experts can prepare the fish, but despite such precautions many persons have died from eating them.

This pufferfish (*Fugu rubripes*) is considered the most delicious of all puffers by the Japanese.

Startled, the marbled pufferfish of the Caribbean begins to puff itself up.

PORCUPINE FISH

Porcupine fish *(Diodontidae)* are related to pufferfish and, like them, have the ability to inflate their bodies when provoked. They are named for the large, bony spines that cover the skin. These spines can be made to stand up at will in some species; in others they can be erected only when the fish puffs itself up. In either case they make the fish a very painful mouthful for the unwary predator. The teeth in each jaw of the porcupine fish are fused together like those of the pufferfish (see preceding page) to form a strong beak, enabling it to crush tough animals like molluscs, starfish and corals for food. Porcupine fish are found in tropical seas around the world. Some species of porcupine fish are poisonous and can inflict painful wounds.

A porcupine fish (*Chilomycteris*) with its ugly mouth gaping open looks vicious enough even when all of its spines are depressed.

A porcupine fish (*Diodon holacanthus*), disturbed by something in the water, has puffed itself up and raised its spines.

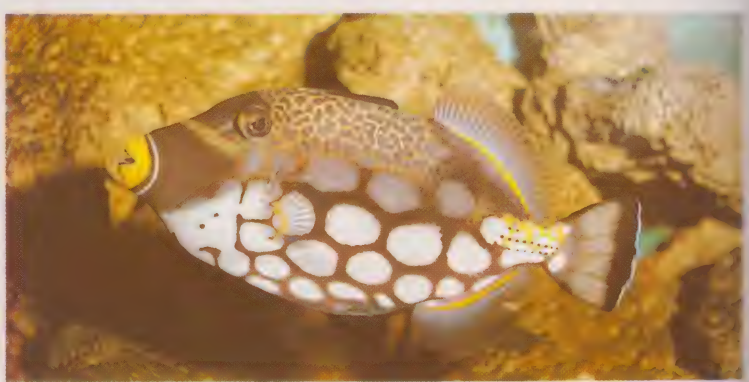
BOXFISH

Boxfish *(Ostraciontidae)* get this descriptive name from a boxlike protective covering over most of the body, made of fused bony plates and containing holes for the eyes, mouth, fins and anus. They are found in warm and tropical seas throughout the world and are considered good to eat. When endangered, boxfish can give off a strong poisonous substance from under the skin. Males often have colourings different from females. Boxfish are also known as trunkfish and cowfish, referring to the hornlike projections that grow from the heads of certain species.

TRIGGERFISH

Colourful fish that are found in tropical seas all over the world, triggerfish *(Balistidae)* are known for a trigger-like mechanism that enables them to erect and then lock into position the first two spines of the first dorsal fin. The erect spines make the fish impossible to be swallowed by predators, and allow them to fix themselves in crevices when they sleep. Triggerfish have rough, spiny scales and strong teeth set in bony sockets in each jaw. In the throat are more teeth that can crush hard food and produce a sort of rumbling noise when ground together.

The bold patterns and bright colours of this boxfish (*Ostracion meleagris*) from the coral reefs of the Indian Ocean match its habitat.



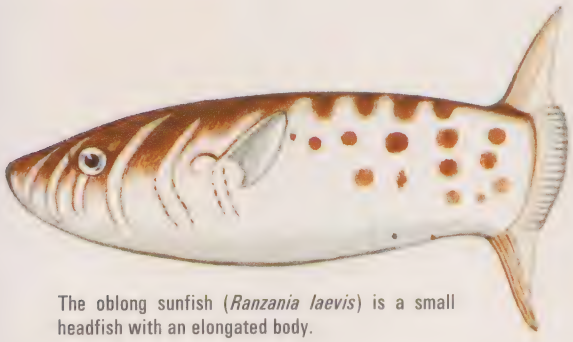
The brightly coloured clown triggerfish (*Balistoides conspicillum*), seen with the spines of its first dorsal fin depressed.

The cowfish, or horned trunkfish (*Ostracion cornutus*). The faint outline of its bony plates can be seen under the skin.

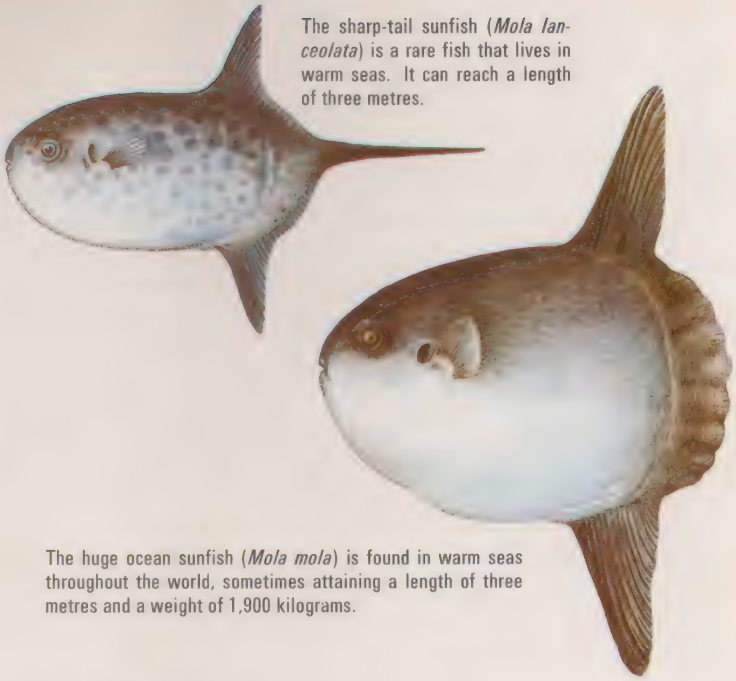
A triggerfish (*Pseudobalistes fuscus*) swims in African waters with the spines of its first dorsal fin standing erect.

OCEAN SUNFISH

Most ocean sunfish, or headfish *(Molidae)*, are huge, oval-shaped animals with short, flattened bodies that end just behind their tall, triangular dorsal and anal fins. They have leathery skin, small mouths and fused, beaklike teeth. Most have short tail fins, but one species is characterised by a long, pointed tail. Ocean sunfish swim lazily with their dorsal and anal fins, often floating on their sides near the surface. When approached by people, they make no effort to escape.



The oblong sunfish (*Ranzania laevis*) is a small headfish with an elongated body.



The sharp-tail sunfish (*Mola lanceolata*) is a rare fish that lives in warm seas. It can reach a length of three metres.

The huge ocean sunfish (*Mola mola*) is found in warm seas throughout the world, sometimes attaining a length of three metres and a weight of 1,900 kilograms.

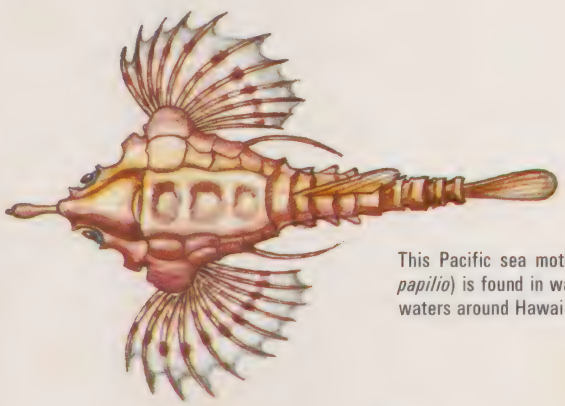
CLINGFISH

Clingfish *(Gobiesocidae)* are small fish that live in rocky parts of shallow seas, although certain Central American species live in freshwater streams. They get their name from their ability to cling to the bottom with a strong suction disc formed from the pectoral and pelvic fins and the skin between them. Members of this family have eyes on the tops of their heads and no scales. Their small mouths have strong teeth, and they feed on small animals.

This clingfish (*Aspasma minima*) is found in tidal pools along certain beaches in Japan.

SEA MOTHS

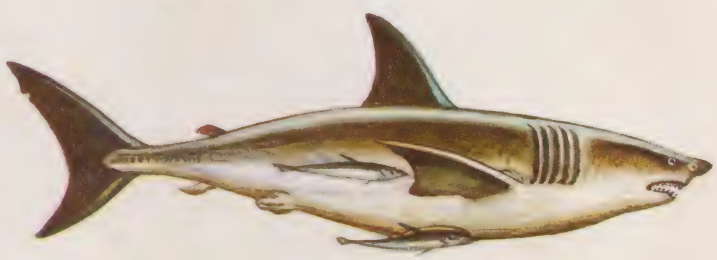
Sea moths, or dragonfish *(Pegasidae)* are small bottom dwellers with elongated bodies encased in armour plates. They have large pectoral fins that resemble wings, but the pelvic fins have been reduced to a few finger-like rays. Their toothless mouths are located under a rather long, bony snout.



This Pacific sea moth (*Pegasus papilio*) is found in warm coastal waters around Hawaii.

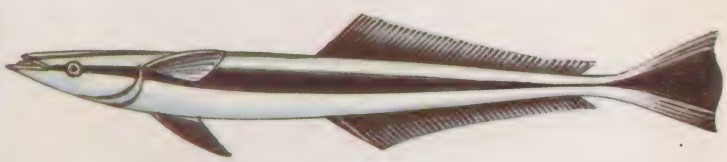
REMORAS

Remoras, or shark-suckers *(Echeneidae)*, are underwater hitchhikers, taking free rides on the bodies of sharks and other fish, whales and turtles —even on ocean-going ships. To achieve this, remoras employ a powerful sucking disc on the top of the head to attach themselves to their transportation. They feed on the leftovers from their hosts' meals, sometimes also acting as cleaners by eating parasites off the bodies of their transporters. The Latin name for remoras means "to delay things," since in ancient times it was believed that the fish were strong enough to stop a ship under sail.



Remoras riding on the body of a shark.

The flat, oval sucking disc of a remora, seen through glass. The disc was developed from the first dorsal fin.

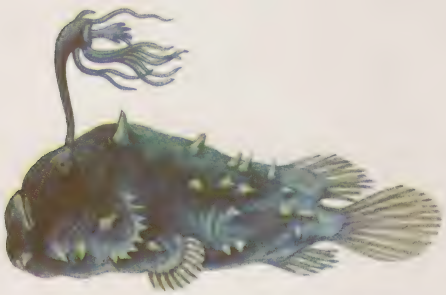


The remora (*Echeneis naucrates*) hitches a long-distance ride by attaching itself to its host with its sucking disc.

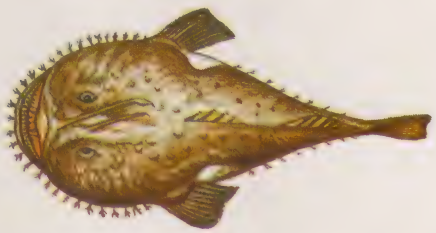
ANGLERFISH AND THEIR RELATIVES

Mostly bottom dwellers in deep water, anglerfish and their relatives *(Lophiiformes)* have enormous heads and small bodies. They have no swim bladder. Some can swallow prey larger than themselves. Anglerfish get their name from the unique way in which they are able to fish for prey. Attached to their heads is a long first dorsal ray that resembles a fishing rod and has at its tip a fleshy "bait" that can be moved about. By dangling this bait close to its huge mouth, the angler snaps up any prey that comes close.

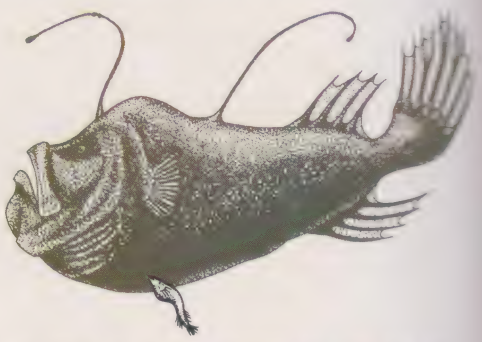
Deep-sea anglers are found in all the world's oceans. The males of certain species are very small and spend their entire lives attached to and receiving nourishment from the body of the female. Frogfish, a group of fish related to anglerfish, can walk on the bottom on their limblike paired fins. They are often patterned to blend with their surroundings, and some can change colour. Certain frogfish drift about in seaweeds, such as the sargassum fish, which is coloured exactly like the sargassum weeds in which it lives.



This sea devil (*Himantolophus groenlandicus*) is a deep-sea anglerfish found in both the Atlantic and Pacific Oceans.



The European anglerfish (*Lophius piscatorius*) lives on the muddy sea bottom, disguised by many small pieces of fringelike skin.



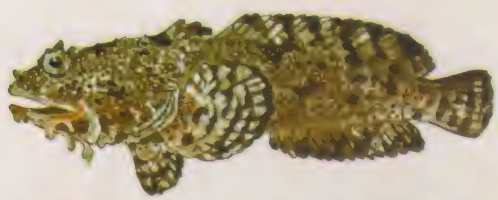
The jaws of a tiny male anglerfish are fused with the skin of the giant female. In return for food it is always present to fertilise the female's eggs.

The sargassum fish (*Histrio histrio*), which resembles a type of seaweed, flourishes in all tropical seas.

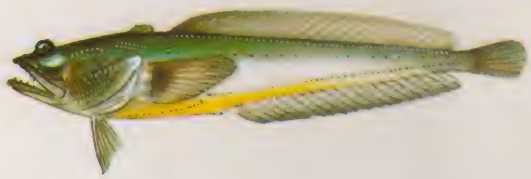
A frogfish (*Antennarius antennarius*) walks on the bottom of an aquarium on its limblike pelvic fins.

TOADFISH AND MIDSHIPMEN

Toadfish *(Batrachoidiformes)* have flattened heads, wide mouths, spiny first dorsal fins and are scaleless. They are capable of making grunting or croaking sounds by vibrating their swim bladders, especially during the mating season. Males are usually quite domestic—they clean the nest, wash and fiercely guard the eggs and look after the young. Members of one group of toadfish, the midshipmen, have small rows of light organs on their bodies that are said to shine like the buttons on the uniform of a midshipman.



The oyster toadfish (*Opsanus tau*) of the eastern United States is called the singing fish because of the sounds it can make by vibrating its swim bladder.

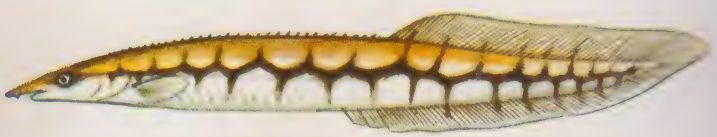


The plainfin midshipman (*Porichthys notatus*) is found along the Pacific Coast of North America.

SWAMP EELS AND SPINY EELS

Despite their names and eel-like shapes, swamp eels *(Symbranchidae)* and spiny eels *(Mastacembelidae)* are not related to true eels. Both are found in fresh or brackish water in the tropics and tend to burrow into the mud. Swamp eels can live in water with a low oxygen content and sleep in the mud during the dry season; spiny eels spend the day in the muddy bottom, emerging at night to hunt for prey. The gills of swamp eels often have only one external opening, a slit in the throat. Spiny eels are characterised by a row of small spines in front of the dorsal fin and a long, movable, very sensitive snout.

The Southeast Asian rice eel (*Fluta alba*), a swamp eel, builds bubble nests and guards its young.



Common spiny eel (*Mastacembelus armatus*) found in swamps from India to China.

FISH IN THE DEPTHS

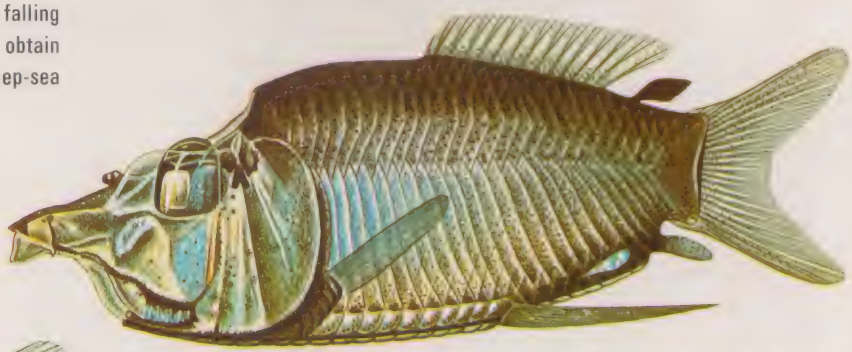
Life is sparse in the dark ocean depths, and very little is known about the strange animals that live there, as they are difficult to catch and have no commercial use. Few studies have been made of the functions of their peculiar organs because the fish rarely survive when brought to the surface. Those with swim bladders die very quickly as they rise due to the tremendous expansion of the gas the bladder contains.

We do know, however, that some of these abyssal fish are provided with curious telescopic eyes, luminescent organs, large mouths and curious body shapes, all of which are adaptations to life in the deep where there is no light and food is scarce. Less is known about how these animals live, except that they prey on bottom-dwelling scavengers of dead planktonic materials falling from the upper waters where life abounds. But we are beginning to obtain information from deep diving vessels called bathyscaphes and from deep-sea photography and television.

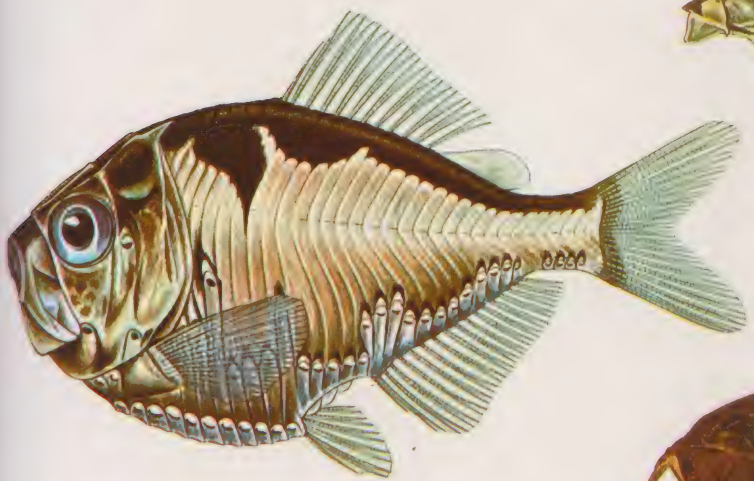
LUMINOUS ANIMALS

Many marine animals produce light. Plankton create the phosphorescence seen in warmer seas, while the searchlight fish and the midshipman are rare examples of luminous surface fish. But most light-producing animals live in deep waters where (apart from them) there is total darkness.

"Living light" in animals without backbones is produced in special cells or in secretions produced from glands and then cast into the water, leaving a luminous trail. The bright glow of luminous fish is produced by bacteria growing in special light organs. Fish use light to communicate and establish their identity, lure prey, and confuse enemies as well as to see in the dark.



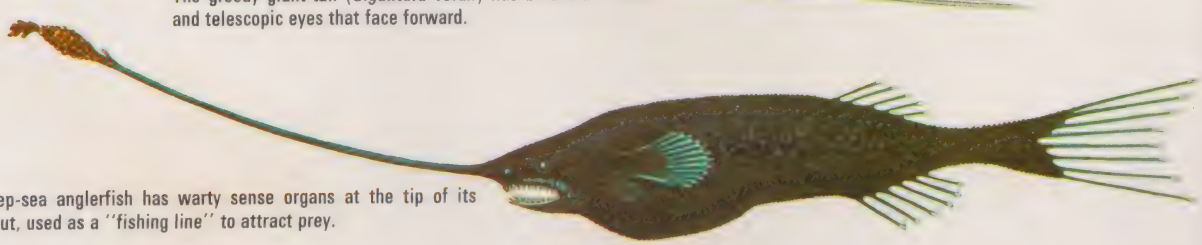
The rare *Opisthoproctus grimaldii* lives 4,000 metres down in the Atlantic. Its eyes are in short, protruding cylinders resembling telescopes and are fixed so that the fish can gaze upward, but not in front of its body.



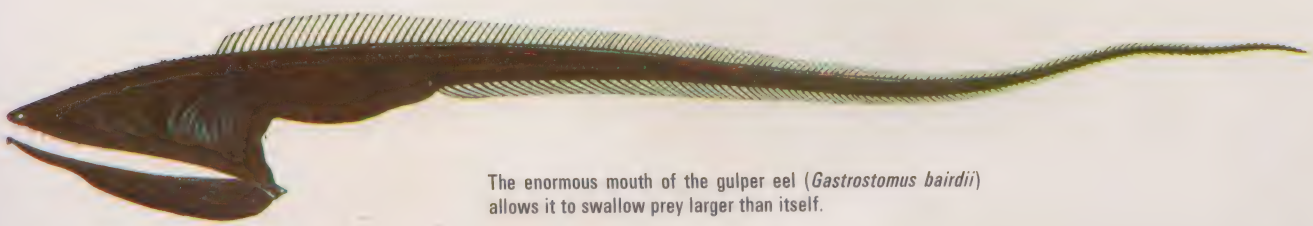
The hatchet fish (*Polyipnus asteroides*) of the North Pacific has many light organs on its underside.

This ferocious-looking fish (*Caulolepis longidens*) has huge jaws armed with large teeth. It must have been a rather menacing vision to the German expedition that discovered it in deep waters of the Pacific Ocean.

The greedy giant-tail (*Gigantura vorax*) has binocular vision and telescopic eyes that face forward.



This deep-sea anglerfish has warty sense organs at the tip of its long snout, used as a "fishing line" to attract prey.



The enormous mouth of the gulper eel (*Gastrostomus bairdii*) allows it to swallow prey larger than itself.

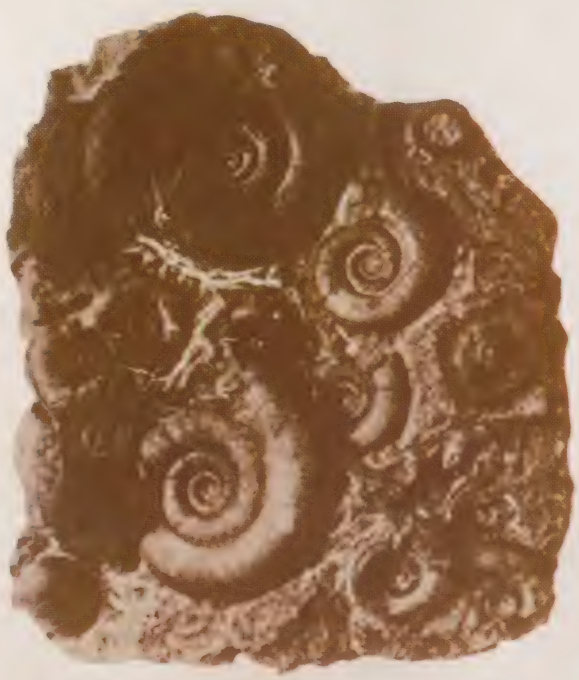
AQUATIC COMMUNITIES

In nature, important relationships between plants and animals bind them together in communities that ensure their common survival. Each community is the result of the interplay of biological, physical and historical forces and is usually able to maintain itself at near self-sufficiency. Each member has made adjustments to the other members and to the surroundings of the community, and each is usually able to blend gradually into neighbouring communities. Thus a typical community centred around a mass of floating kelp off the coast of California may contain several kinds of fish, three dozen or more invertebrate animals, bacteria, algae and protozoans and possibly even a swimming mammal, all of which live in harmonious balance—or will if people let them alone.

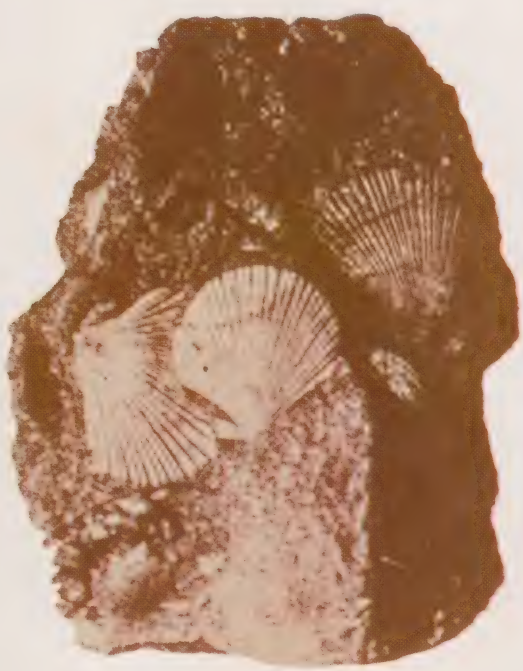
But people interfere in a number of ways. Sometimes the wild creature will find a way to adapt to this interference, sometimes not. The salmon—to supply one example—returns from the ocean to spawn in the stream where it was born two or three years earlier, often swimming many miles upstream and even leaping over waterfalls. But today many of our rivers are blocked by

Psiloceras planorbis, an extinct species of Mesozoic-Era cephalopods.

Trigonia pocilliformis—an extinct species of Jurassic-Period molluscs.



Pecten valoniensis—an extinct species of Jurassic-Period sea scallops.



Fossils that date back hundreds of millions of years reveal to us the types of life that existed then in long-vanished oceans. There were then, as there are today, communities of underwater life, and some of these ancient specimens have survived all the intervening time. Many of them failed to adapt and became extinct. But these stories in stone help us understand how marine life evolved into what it is today.

dams or are too polluted for the salmon to use. In some cases salmon cut off from their home spawning grounds may start a new run up another river. Fish that become trapped in polluted waters, however, often die or become so contaminated that they are not edible.

Pollution of waters has become a serious matter in our lifetime, and we must consider what long-term biological effects this will have on future generations of plant and animal life. Our seas have become dumping grounds to the extent that even in mid-ocean refuse can be found floating in tremendous patches—later to accumulate on the bottom of the sea. If people expect to continue to depend on the oceans and their fish and plants as a source of recreation and food, the ecological balance of their waters—no less than that of rivers and lakes and the land—must be conscientiously protected against dumping of waste. Dredging operations, as well as construction of barriers in the ocean in an attempt to control water or air temperatures, can be equally damaging by driving marine life out of natural habitats, thereby disrupting the community and upsetting the food chain.

The lesson is that if we continue to strain the ecological chain and break any of its links, humanity will suffer. But if we keep the waters clean and respect nature's system of checks and balances, the waters and the life in them will remain healthy and available for our needs.

Four views of thriving present-day communities exemplify the interdependent underwater world. We can see the mutualism between a shrimp and a sea anemone, top left. A shoal of fish illustrates the collective behaviour of one species, top right. Wrasses, starfish, chitons, tubeworms, turbos and seaweeds live together around a rock, above left; and on another rock, above right, many generations of barnacles have colonised a rock on the seashore.

Simple net fishing can help sustain small communities or large families, but this means of fishing can be depended on only seasonally and locally.

SAVING THE FISH

Next time you have fish for dinner, reflect for a moment on the tremendous energy chain that went into the production of that animal. Suppose your serving is 100 grams. It is estimated that it takes 100,000 grams of marine life to produce the 100 grams of fish on your plate. First, it takes 10 grams of phytoplankton to produce one gram of zooplankton; then 10 grams of zooplankton to make a gram of the smaller forms of marine life that fed your fish, which consumed about 20 kilograms of food to achieve the two kilograms it weighed when it was caught.

If you are impressed by these figures, consider the amount of fish taken from the oceans each year. Since the mid-1940s the consumption of fish has risen almost eightfold to 70 million metric tonnes in 1975. About 85 per cent of these fish have come from the sea, which has always been a reliable and constant source of food. Now many people are worried about whether it can continue to be so. Some of the major fishing nations are sending to sea such technologically efficient fishing fleets that they, in effect, vacuum the fish from the great fishing grounds off the Northeast United States and Southeast Canada, where the haddock has become threatened with commercial extinction; the Bering Sea, whose shrimp population is similarly threatened; and the Northwest Pacific, where intensive fishing has depleted fish stocks dangerously. By the end of the 1970s, the refusal or failure of the big fishing nations to accept a limit to their catch led many nations to extend their control over fish resources to 322 kilometres and to impose strict quotas in an attempt to rejuvenate depleted fish populations. It may take years, however, before we know whether these measures are enough to save fish populations.

Modern fishing boats with their massive nets and fish-finding equipment are tremendous improvements over the simple nets, but they still must hunt fish, whereas many environmentalists believe that farming fish would be better.

A sonar operator seeking fish adds to the efficiency of the fishing fleet, but in some areas this is seriously depleting the fish population.

The day's catch of only one ship gives some idea of the tremendous numbers of fish that are caught by thousands of ships around the world.

POLLUTION AS A THREAT TO LIFE

In late March, 1978, the American-owned supertanker Amoco Cadiz went aground and broke in two off the Brittany coastline of France. In two weeks it spilled 220,000 tonnes of crude oil—history's largest spill—into the sea and fouled beaches for 160 kilometres. Untold numbers of fish were killed, as were thousands of marine birds. An important seaweed crop was all but ruined, and no one knows how much damage was done to plankton and seaweeds at the beginning of the ocean's food chain.

In 1973 a Japanese chemical company, Chisso, was convicted of polluting Minamata Bay on the west coast of the Japanese island of Kyushu by discharging its waste, which contained methyl mercury. Years earlier people eating fish out of the bay had become victims of mercury poisoning; lips and limbs tingled, then went numb, muscles became uncontrollable, speech became slurred. More than 800 people have been certified as victims, and more than 100 of them have died.

Every day factories spew their poisons into rivers to be carried out to the sea. In many cases this is done deliberately, with little knowledge and less concern for the devastating damage to underwater life and its part in the world's food chain—simply because it is cheaper to dump the waste into rivers than to find alternative methods of disposal. The dumping of wastes and poisons into once healthy waters is a problem that is spreading faster than our knowledge of the disastrous results it may produce. Here, conservationists believe, is one of the gravest threats to our oceans.

This infrared photo of San Francisco Bay shows pollution of the water by inland industrial waste in river outflows. The polluted portions of the bay are those where irregularities in the colour of the water are visible.

THE NEW FRONTIER

If the French science-fiction novelist Jules Verne, author of "20,000 Leagues Under The Sea," were alive today, he would doubtless marvel at some of the equipment and machines that have been developed for underwater exploration. The aqualungs that allow the diver to breathe air underwater for long periods, the swim fins for swimming faster and the rubber suits for protection in cold water are only the beginnings of undersea exploration by humans.

In the 1950s French undersea explorer Jacques Cousteau and his team of divers used aqualungs to dive deeper than 100 metres. Using a special diving vessel—a bathyscaphe, or "Depth-craft"—Cousteau made dives down to 1,400 metres, but the first deep-sea dive to the ocean floor was made by two French naval officers in 1954 when they descended to 4,000 metres. Today oil explorers use a huge robot-like, one-man suit with handlike claws that can work on equipment as much as 500 metres deep. Another submersible can carry five people and work at depths of 600 metres; it has manipulator arms that perform many of the tasks of a human hand. And Japan's Marine Science and Technology Center in 1978 announced that it had developed a device that takes photographs 6,200 metres deep. Already we can foresee a time when underwater parks will be possible. Such parks, in addition to providing food, can become recreational retreats that people may enjoy the same way they now enjoy national parks on the land—not at the depths Verne wrote about in his account of an underwater voyage, but deep enough to reveal the seas' mystery and beauty to everyone.

Unlikely as the possibility may seem, this underwater gear of the 19th Century was for die-hard sea lovers who tried recording the wonders beneath the surface.

WHY WE SEARCH THE SEAS

You may wonder why scientists go to the bottom of the sea to study sea animals that people rarely see and cannot eat. Actually, the lack of food is not the only major problem facing the world's human populations. As a species, we humans are not particularly well adapted to environmental conditions compared to the many hundreds of species of underwater animals. We must use technology to protect ourselves from violent natural forces. We can search the seas and travel the skies, but still we cannot assure ourselves enough food, and we cannot wipe out disease. If humans were left to the rigours of the natural environment, most would perish. In short we need to learn how marine animals can survive under such difficult conditions as we find in the sea. For instance there is a sea slug which lives at a depth of 10,000 metres. How the cells of this creature's body are able to withstand such incredible pressure is of interest to the biophysicist, for knowing this may in some way benefit technology when the information is applied by engineers to underwater vehicles and housing. The sheer numbers of species of underwater life is evidence of the many ways that living things have adapted to the problems encountered in their environment. Maintaining this great variety is essential for the survival of all, as they have become interdependent. By studying natural adaptations such as those that occur in the sea, we may improve not only our own way of life but will discover how we too are interdependent on a variety of species. Another goal of many marine biologists is to save the underwater populations from extinction.

Amidst colourful Caribbean crinoids and sponges, a diver injects fluorescent dye into a sponge. By using this method he can study the animal's feeding system by following the passage of the dye through the digestive system and seeing where the dye is ejected.

A diver with modern photographic equipment promotes both art and science as she photographs some of the colourful sea animals —in this particular case a sea fan and a sponge that live beneath the surface of the sea.

Safe inside an underwater vehicle, (opposite), a scientist observes and records the behaviour of a shark. The alternative would be descending in shark cages, which is dangerous, because sharks are among the most vicious of fish, and some species will attack almost anything that moves.

Underwater apparatus for testing water samples is shown above. Researchers determine the chemical composition of the water as well as what sort of microbe life it contains. Through such research humans are able to help with problems that occur to plague underwater beings.

In our study of the sea, we can use not only our technology, but also the help of our friends, in this case the dolphin, which has a long history of helping humans. The dolphin's echolocation equipment has aided human study of sounding devices.

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